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In This Issue:

It's Not What's Said, It's Who Says It 130

The Hydrogen Bomb
Robert F. Bacher 133

The Canadian Atomic Energy Project
W. Bennett Lewis 139

Planning for Atomic Physics in Norway
Gunnar Randers 142

On Negotiating with the Russians
Hans J. Morgenthau 143

Occurrence of Uranium Deposits
W. H. Bradley 149

AEC Seventh Semiannual Report: A Condensation
Anthony Turkevich 153

"Atomic Medicine"
Reviewed by George LeRoy, M.D. 160

Drawings by Martyl

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IT'S NOT WHAT'S SAID IT'S WHO SAYS IT

THE story is told that in the days of the Manhattan District, a scientist was summoned to Washington and reprimanded for having mentioned in public a physical constant which was still secret. The accused fingered through the Smyth Report and pointed to a number there. "Yes," said the security officer, "but that is in pounds per square inch, while you gave the figure in kilograms per square centimeter. Why make it easier for the Russians?"

This story may be apocryphal, but the hope that the Russians may not know how to use the multiplication table — not to speak of their inability to read the *Physical Review* and to apply commonsense and some imagination to what they have read—dies hard in the minds of the guardians of our atomic secrets, even after the announcement of the Soviet atomic explosion last September. Otherwise, how can one explain an occurrence like the suppression of a part of Professor Bethe's article on the hydrogen bomb (published, in the "expurgated" version, in the April issues of the *Bulletin* and *Scientific American*)? From the text of the telegrams sent by the AEC to its scientific employees at the time of this incident, and from public statements made in connection with it, it appears that the objectionable paragraphs dealt with the role of heavy hydrogen isotopes, deuterium and tritium, in a thermo-nuclear bomb and did not contain anything which has not already been said publicly on this subject by scientists not associated with the Atomic Energy Project. If this is true, then the arguments presented by the AEC in support of its action are not too convincing. The physical data needed to estimate the speed of nuclear reactions between the three hydrogen isotopes have been published in *Physical Review, Nature,* and other generally accessible journals, some as recently as the summer of 1949. The declassification authorities of the AEC and of the British atomic research project have permitted publication of these figures. Probably they did so in the sound belief that Soviet scientists are quite able to make these measurements themselves and that the most that could be gained by withholding from publication the results obtained at Los Alamos and Harwell would be to cause a couple of Soviet physicists to spend a few months on this investigation — an advantage which would not compensate for the damage done by depriving American (and other non-Soviet) physicists, outside the Atomic Energy Laboratories, of basic information which they might need for their theoretical and experimental work.

* * *

While crediting the Soviet scientists with the capacity to determine nuclear constants, the AEC apparently does not credit them with the capacity to draw simple, logical conclusions from the results of these measurements, nor to judge whether the conclusions made by American scientists who have discussed the subject in public, are scientifically sound. And yet, the conclusion that the rare hydrogen isotopes are the most likely materials for thermo-nuclear bombs is an obvious one for every nuclear physicist familiar with the published data. From the known rates of the nuclear reactions between these isotopes any physicist can calculate the temperatures and pressures needed to make these reactions proceed at a given speed. The results of these calculations will be the same whether they are made by Dr. Bethe, a world authority on thermo-nuclear reactions, or by a candidate for a Doctor's degree in physics at some remote university in the Soviet Union. The argument that because Dr. Bethe is a consultant to the AEC, and therefore "on the inside" of the American atomic bomb research, he should not refer to these conclusions is only slightly more convincing than would be the proposition that Dr. Condon should not publicly convert inches into centimeters because, as the head of the U.S. Bureau of Standards, he speaks on this subject with an authority not possessed by others.

* * *

In this issue, we reprint the abovementioned telegrams sent by the Atomic Energy Commission to its scientific employees on March 14 and 17, respectively. The first was a peremptory order not to discuss *anything* pertaining to thermo-nuclear weapons—whether it be classified or non-classified information, technical or nontechnical—with anybody outside the project. In the press conference held by the AEC on March 29, the Commission denied that this order had caused excitement among scientists, although it owned to a few telephone calls. Either impressed by these calls, or on their own second thoughts, the AEC issued a new directive three days later, in which it apologized for the tone of the first telegram and substituted, for the original *order*, a polite *plea*. It also specified that the request applied only to technical and not to political aspects of the H-bomb. In essence, however, the directive remained the same: not to discuss in public the thermo-nuclear reactions which might be relevant to the H-bomb construction, even if this discussion would not reveal any classified information.

A reporter at the AEC press conference asked where this leaves the *Bulletin of the Atomic Scientists,* whose board contains so many prominent nuclear physicists associated with the AEC. "Will they be able to continue publication?" he asked. The answer is that the *Bulletin* intends to continue publication on the same principles as before: It never has submitted nontechnical material to censorship, and does not now intend to do so. Surely, the AEC does not want to exercise such a censorship. The *Bulletin* will be as careful as it has always been not to reveal any classified technical information. (To the best of our knowledge, in the five years of its existence, the *Bulletin* has not once sinned against this rule—which is more than can be said of some Senators, high military officials, and industrial firms, associated with the Atomic Energy Project.) The only difficulty arises in the border region, where scientific data are used to draw conclusions concerning the prob-

able developments in the weapon field and their political implications. Whether speculation of this kind, emanating from scientists associated with the AEC, even if they are careful not to reveal any restricted data, nevertheless goes beyond what any intelligent physicist could derive from publicly available information, and permits guesses about secret information to which the author presumably had access, is a matter of judgment. No formal rules or criteria can be established in these cases, since even the most innocent statements—such as that the speaker intends to return to his university in six months—may be interpreted as carrying important implications. The *Bulletin* believes that judgment in this field can best be exercised by responsible scientists themselves, and intends to continue relying on their judgment.

Unlike many journalists, scientists are fully aware of the fact that technical security restrictions apply not only to *what* can be said but also to *who* can say it. They have been familiar with this distinction since 1940; often they have had to restrain themselves from correcting errors or confirming the truth of statements made by laymen, or by fellow-scientists without access to secret information, realizing that things they say have an authoritative implication. They appreciate that the situation which called for secrecy in certain scientific fields—which all hoped would end soon after the war—is still with us five years after the hostilities have ceased. They feel that in these matters, they can expect not to be treated as irresponsible children who cannot restrain themselves.

Commissioner Smyth, in public debate with Mr. Piel, the Editor of *Scientific American*, called upon scientists to acknowledge that they cannot adequately judge the implications of their own statements, and to let the AEC, which alone has a complete picture of the situation, make the decision for them, by submitting all their articles and speeches which even remotely touch upon the subject of atomic weapons, to a preliminary censorship by the AEC.

Our quarrel is not with the principle that scientists (and not only scientists) who have access to secret information should consider their public pronouncements on the subject of atomic weapons much more carefully than those outside the project, and that whenever any doubt arises in their minds, they should consult with the AEC before publication. It is the blanket extension of this principle, implied in the AEC telegrams, and exemplified in practice by the case of Dr. Bethe's article, that causes grave apprehensions. What is dangerous is not so much the actual infringement upon the rights of free speech of scientists, and the possibility that reprisals may be taken against them and the publishers who print their statements. Rather, it is the effect of such censorship on the willingness of many valuable scientists to be associated with the AEC, and the willingness of the scientists already associated with the AEC to participate in public discussion of any kind, and particularly in the discussion of crucial political and military decisions in which they alone can give the nation informed and badly needed advice. Whether the harsh procedure used in the case of Dr. Bethe's article was intended to serve as an example or not, it undoubtedly will cause many AEC scientists in the future to think twice before accepting an invitation to write or speak in public, even on subjects remote from the hydrogen bomb. The initial success of totalitarian regimes in silencing all expression of independent opinion has been based only in part on actual reprisals, or fear of reprisals; to a large extent it was founded on the unwillingness of most people to tangle with the police and censorship. It is simpler and safer to stick strictly to one's own business than to try to take part in public affairs if this participation is obviously frowned upon and surrounded by bothersome regulations. Would it be in the best interests of the nation if scientists in America were to become technical specialists working on assigned topics without interest in the implications of their work for the future of the nation, and without any feeling of obligation to take part in the formation of national policy in the field where their contribution to democratic processes could be most valuable? We do not believe so.

* * *

With the same right with which the AEC can ask its scientists to be cautious in their public statements, scientists can and must ask the AEC to be cautious in the exercise of the broad powers vested in it by the Atomic Energy Act. American scientists have given no reason to doubt their discretion and their judgment as to what should and what should not be said in public.

Need it be recalled that it was the physicists who instituted voluntary censorship on the discussion of uranium fission in 1939, and refrained from public discussion of thermo-nuclear explosions until Senator Johnson and the Alsop brothers made the continuation of this restraint useless?

Dr. Bethe, in particular, is on record[1] as having deplored the fact that the hydrogen bomb has been made the subject of public discussion. He has argued that in 1950, not less than in 1945, it would have been better to continue the exploration of the field of thermo-nuclear explosions without public fanfare. We believe that Dr. Bethe's judgment as to whether or not his discussion of the hydrogen bomb could have added—directly or by implication—to the knowledge the world outside has of the state of American efforts in this field, should have been respected by the AEC. That it was his article which was selected to "establish a precedent" is particularly unfortunate. We hope that the incident will remain isolated, and that steps will be taken to re-establish trust and understanding between the AEC and the American scientific community.

* * *

Americans are accustomed to hearing their military and political leaders and experts, from the President and Defense Secretary down to colonels and captains (not to speak of members of congressional committees) talk publicly about matters of military preparedness, national strategy, and tactics—although the access of these officials to secret information cannot but influence their statements. Even when they have used this information rather recklessly—as in last year's controversy over the B-36 and strategic bombing—no attempt was made to muzzle them. Some things said in the heat of this controversy, would have been better left unsaid; but

[1] *Bulletin*, VI (April 1950), 103,106.

on the whole, public discussion of fundamental aspects of national military planning, of the armed forces and the weapons available to the nation, and the ways in which they are intended to be used, belongs to the democratic way of evolving national policies. Fission bombs, thermo-nuclear bombs, radioactive poisons, and bacteriological weapons cannot be excluded from this discussion without making the American people blind to some of the most important elements affecting our political and military decisions.

In this discussion, scientists who have the most complete knowledge of the facts, and the deepest understanding of the possibilities, have the right (and the duty) to participate, since they are best able to enlighten public opinion. The judgment they have shown so far does not justify apprehension that they will speak out too lightly or irresponsibly. —E.R.

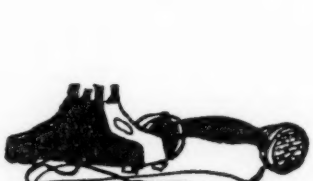
Text of AEC Directives

On March 14, the following wire was dispatched from the New York office of the AEC to all AEC employees and consultants:

"Your attention is directed to the following instructions from the USAEC prohibiting discussion of thermo-nuclear weapons with unauthorized persons regardless of classification of the information. This means that until further notice no information on this subject can be made public by people working for the AEC or for contractors on AEC projects. All AEC and contractor employees working on AEC contracts are instructed to refrain from publicly stating facts or giving comment on any thermo-nuclear reactions of the Commission's program of thermo-nuclear weapon development. Please make sure the foregoing instructions are immediately brought to the attention of persons working under contracts with this office and are strictly complied with."

On March 17, the "instructions" were altered in the following "request":

"Reference is made to my telegram dated March 14, 1950. The following explanatory message from the General Manager, USAEC, Washington, is forwarded for your information and guidance. Quote. This message is to further explain and interpret my previous messages concerning the Commission's desires in the matter of release of information on thermo-nuclear weapons. I regret the abruptness and tone of the previous messages which it is recognized were not sufficiently explanatory. The assistance and cooperation of all employees of the Commission and contractors and all Commission consultants is requested in seeking to avoid the release of technical information on thermo-nuclear weapons by persons closely associated with the Atomic Energy Project. The purpose of the Commission's request on this matter is for the time being to avoid release of technical information which even though itself unclassified may be interpreted by virtue of the project connection of the speaker as reflecting the Commission's program with respect to thermo-nuclear weapons. This of course applies only to technical information and conclusions based thereon. We are confident that project-connected personnel are aware of their responsibility and duty not to add or elaborate or confirm information concerning the superbomb or the thermo-nuclear reaction if such action expands the known technical knowledge of this weapon. This would still permit unclassified discussions of what might be called the classical thermo-nuclear reactions as long as there is no reference to their relation to weapons. This message should be relayed to all AEC contractor employees and all consultants as a request for their cooperation and to interpret the policy basis of my previous request as a necessary interim measure. Signed, Carroll L. Wilson. Unquote. Please inform your employees working on AEC contracts with this office of the contents of the General Manager's message."



FAS Protest Commission's Ban on Discussion

The Council of the Federation of American Scientists has protested the AEC's action in ordering its employees to remain silent about non-secret scientific aspects of the hydrogen bomb. We quote from the Council's statement issued on April 30:

"American scientists have proved their discretion in acts through more than a decade of secret work, work which helped bring American victory and the first atomic bomb. Neither members of Congress nor high commissioners have a better security record. Idle and careless talk has not been the habit of scientists.

"The Federation of American Scientists believes not only that scientists have the right to speak up, but that they have the duty of explanation. They need to talk, when no military security is involved, but when great decisions are made without adequate accounting to the people.

"This responsibility, shared by all men and women of special training, is never easy to fulfill. It has been made many-fold harder the last weeks. The first printed version of a serious and important article, written by a prudent and careful scientist, has been burned by order of the Atomic Energy Commission. We have heard of no one of the scores of reputable readers of that original article who found in it any appreciable amount of information still properly to be kept secret, or not widely known to specialists all over the world. It was not secrets which were thus protected; it was the raw material for public understanding which went up in smoke. These are not times in which ignorance and misinformation can be the basis of public opinion. Every thoughtlessly erected barrier between Americans and their right to know and to speak is a threat to the welfare and security of the nation.

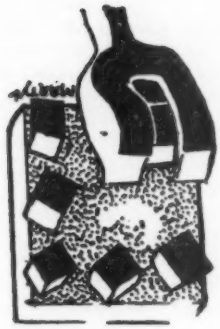
"We urge that any policy which presses into silence both individual scientists, and the newspapers and other organs of information be sharply and promptly revised."

Science Foundation Bill Passed by Congress

April 27 and 28 saw the passage of the bill (S247) establishing a National Science Foundation. The drastic loyalty and security provisions included in the Smith and Flood amendments to the House bill were modified in the House-Senate conference. The *Bulletin* will print the text of the bill and comment upon it in the next issue.

THE HYDROGEN BOMB

Robert F. Bacher



In the following article Robert F. Bacher, a former member of the U.S. Atomic Energy Commission, discusses the new weapon in terms of its military effectiveness and asks for the release of enough information to enable the public to take its rightful part in deciding crucial questions of national policy. Dr. Bacher is head of the Physics, Mathematics, and Astronomy departments at the California Institute of Technology.

ON JANUARY 31 President Truman issued a short and momentous statement about the hydrogen bomb. Quoting the central part of his statement, he said "I have directed the Atomic Energy Commission to continue its work on all forms of atomic weapons, including the so-called hydrogen or superbomb. Like all other work in the field of atomic weapons it is being and will be carried forward on a basis consistent with the over-all objectives of our program for peace and security."

There has been no amplification of this statement.

During the weeks before the President issued his statement and in the following weeks there have been many conflicting statements about hydrogen bombs and what we should do about them. Some of these statements have become distorted in repetition. Others, while clearly stating physical possibilities, concern events which are so improbable as not to warrant serious consideration at the moment. Some of the statements made by scientists, whether intentionally or otherwise, have been very frightening to our citizens. Back of such statements seems to be the idea expressed by some, that if the United States citizen will just become sufficiently frightened somehow we will not have any war in the future.

There is no question that the hydrogen bomb has terrifying possibilities, and a little later I shall try to give some estimate of what such a bomb might be like. It is our very deep obligation, however, as citizens in a democratic country to consider this whole question objectively, dispassionately, and as carefully as we can under the circumstances to decide just what our country should be doing. It will not improve the judgment of the citizen to scare him to death first. This is a very serious time for the United States. We cannot afford any irrational or purely emotional action. Our future safety and security depend today on keeping our heads and using wise judgment.

THE MORAL PROBLEM

Many people in considering the national policy on the hydrogen bomb have been able to formulate their opinions of this weapon very quickly on moral grounds alone. They say, and with justice, that the hydrogen bomb is a weapon of tremendous mass destruction and that, accordingly, no civilized country should consider its possible development and use. This is a comfortable position and one very easy to take, but where do we stop? Atomic bombs are also weapons of mass destruction. Are they moral or immoral? Nothing could be more gruesome and immoral than the reports which many of us have heard of some of the hand-to-hand conflicts during the past war. Nothing could be more uncivilized than some of the torture to which war, conflict, and slave states have led.

There is no question about it. War inevitably leads to many acts which are immoral. The relative immorality of various weapons and acts of war becomes difficult to distinguish. The hydrogen bomb, being a weapon of tremendous destruction, is more to be condemned than lesser weapons on these grounds if used for needless mass destruction. Indeed, no one can argue that the moral position of the United States will be improved by the possession or use of this bomb. Immoral as it is, war consumes a large part of the efforts of the people of the world. Situations arise in which war seems to be the lesser of two evils. The moral problem is therefore a much deeper one. The real question is: "What should the United States do in order to diminish the probability of world conflict and to increase world peace and international accord?"

To this question many answers are given. One man will say that the only approach is pacifism. Another man will say that the only approach is to be fully and completely prepared to act against any aggressor immediately and effectively. The problem seems to be much more subtle. No such simple solution has been found in the past to be effective.

I have no complete answer to this question. But what we do about the hydrogen bomb in the future may affect world peace and is directly related to this basic question. One man says that to make the hydrogen bomb starts us on a weapons race which will inevitably lead to war. Another man says that we can only maintain our security if we make hydrogen bombs and thus are able to hold an aggressor at bay. Which one is right?

Many of our citizens have lost all faith in the United Nations and believe that there are no possibilities at all for international agreements which will have any meaning. Others feel that we have not made the right approach to the Russians as yet. Certainly there is little reason from our experiences in the United Nations, and particularly from our experiences and

A talk given at Town Hall, Los Angeles, March 27, 1950.

efforts toward the international control of atomic energy, to be very hopeful. While yielding no tangible results, these discussions of the control of atomic energy have been very useful in pointing out where the difficulties lie.

Our Secretary of State, Dean Acheson, stoutly maintains that if the Soviet Union will face the real needs for international agreement on vital issues and will show a desire to reach agreement, then it would be possible to lessen the tension which grips the world today. While he is not optimistic on Soviet willingness to decrease that tension, he believes that accord on the international control of atomic energy is one of the vital issues. If international accord seems so unlikely, we should be interested in whether a vigorous development and production of the hydrogen bomb will increase or diminish the probability of war.

Of course there will be some who will argue that any weapon development at all leads to war and therefore we should make no development of any kind. Though this is in agreement with some of our most deeply rooted Christian ideas, it cannot be followed. There is no question at all in my mind that for our nation to pursue such a policy in the present world would be for us greatly to increase the probability of a world holocaust and a national calamity.

Throwing aside then such a pacifist view, let us ask the questions: What weapon development is important to the national security? How important is the hydrogen bomb to national security? Will hydrogen bombs increase our chance of winning a war with minimum loss?

EVOLUTION OF H-BOMB THEORY

Before trying to answer these questions, let us look briefly at some of the technical background of the hydrogen bomb. It has been known for a great many years that if one could somehow find a way of putting light atomic nuclei together to make heavier nuclei, it would be possible to extract energy. It has also been known for a long time that if one could take the heaviest nuclei and split them apart, one would be able to obtain energy.

The first indication that either of these processes might be important to us as a source of energy came from the suggestion by Hans Bethe that the fusion of the light elements was our fundamental source of energy in the sun and stars. Dr. Bethe worked his ideas out in some detail, and scientists now believe that this is the origin of solar energy. These ideas were well developed before the fission of uranium was discovered. The discovery of the fission of uranium in 1938 was immediately recognized as a possible source of energy for man. Released gradually, this energy could be used for power. Released suddenly, this energy could provide an explosion.

Two fundamental scientific discoveries which followed soon after the discovery of fission were of far-reaching importance. The first of these was that in the fission of uranium caused by the absorption of low energy neutrons, additional neutrons were released in the process. The importance of this fact is that the fission of uranium could produce neutrons which could then produce another fission, hence the term "chain reaction." These neutrons released in fission could make the reaction self-perpetuating.

The second discovery was that some of these neutrons were emitted some time after the fission took place. It was this fact that made the controlled chain reaction or nuclear reactor a possibility. Without these delayed neutrons we would have no way of controlling a nuclear reactor.

With the fusion of the light elements the situation is entirely different. Here the basic nuclear reactions which lead to the release of relatively large quantities of energy are those which occur when the nuclear particles collide at high velocity or high relative kinetic energy. At the center of the stars the temperature is many millions of degrees centigrade and the particles of matter are moving at such high speeds that these nuclear reactions may take place. Even then, only a few nuclear reactions are possible. There is no possibility that the energy release from this type of reaction can be controlled on the earth. In the stars the reaction is controlled because of their great size. On the earth these self-sustaining thermo-nuclear reactions will either give an explosion or nothing at all.

Whether or not a hydrogen bomb can be made depends upon whether it is possible to create, on earth, an assembly of materials which will produce a nuclear reaction if heated to a sufficiently high temperature, and then to devise a way to raise these materials to that temperature.

The temperature required is comparable to that reached in the interior of the sun, which is more than ten million degrees centigrade. The only way that we know to reach such a temperature today is in an atomic bomb, where the sudden release of energy causes the materials of the bomb to be heated to an extremely high temperature.

The main light element, of course, to which I have been referring is hydrogen. Now ordinary hydrogen just won't work. The scientific evidence for this seems to be quite clear. But hydrogen as it is found in nature has two forms or isotopes. The heavy hydrogen discovered by Urey nearly twenty years ago, is a possibility. In recent years heavy hydrogen, as contained in water, has been separated in relatively large quantities.

There is another possibility. For more than fifteen years it has been known that another isotope of hydrogen, called tritium because it has mass three, is produced in nuclear reactions. This material is radioactive and ordinarily does not exist in nature. It has a half-life of twelve years, but its nuclear properties are such that it is of basic interest in the release of energy by fusion.

It has been known for many years that tritium could be produced in a nuclear reaction in which neutrons are absorbed. The big nuclear reactors which are now in operation do produce neutrons in large quantity. These neutrons are ordinarily used in the production of plutonium. But they could be used just as well to produce quantities of tritium. Any nuclear physicist can sit down and figure out the theoretical limit of the amount of tritium that can be produced with a given number of neutrons. He would quickly recognize that since you need neutrons to produce plutonium and neutrons to produce tritium, a nuclear reactor could be used to produce one or the other at will. It would be necessary, of course, to know a great deal about the actual workings of a nuclear reactor in order to say just how much tritium could be produced in that reactor if one were willing to forego the production of a certain amount of plutonium. It sounds as if the production of tritium in quantity is at least a fairly expensive if not formidable process.

That these two isotopes of hydrogen can possibly play a fundamental role in the release of nuclear energy by fusion is well known. Just exactly what relative role they play, and how they might play it, is not a subject for open discussion today. These questions are secret, and we can have no discussion of them. But any nuclear physicist will quickly grasp the basic science requirements even though the bomb technology is much more complicated.

The real problem in developing and constructing a hydrogen bomb is: How

do you get it going? The heavy hydrogens, deuterium and tritium, are suitable substances if somehow they could be heated hot enough and kept hot. This problem is a little bit like the job of making a fire at 20 degrees below zero in the mountains with green wood which is covered with ice and with very little kindling. Today scientists tell us that such a fire can probably be kindled.

Once you get the fire going, of course, you can pile on the wood and make a very sizeable conflagration. In the same way with the hydrogen bomb, more heavy hydrogen can be used and a bigger explosion obtained. It has been called an open-ended weapon, meaning that more materials can be added and a bigger explosion obtained.

WHAT THE HYDROGEN BOMB WILL DO

Let us look for a moment at what sort of an explosion is imagined. Here I shall take the figures which have been commonly reported in the press and stick to round numbers. I believe that these are quite adequate to give some general idea of what such an explosion is like.

In 1945 President Truman stated that the atomic bomb was equivalent to twenty thousand tons of TNT. In talk about the hydrogen bomb it has commonly been speculated that such a bomb would be one thousand times as powerful as the bomb dropped on Hiroshima. If it is one thousand times as powerful, this would mean that it would have an explosive effect equivalent to about twenty million tons of TNT.

Now it happens that the radius of damage from a big explosion increases as the cube root of the energy released. With a bomb a thousand times more powerful than the Hiroshima bomb, the radius of damage will be ten times greater. Since the radius for almost complete destruction from blast was approximately one mile at Hiroshima, the corresponding radius for a hydrogen bomb one thousand times as large would be approximately ten miles.

Such a hydrogen bomb would be sufficiently great to cause almost complete destruction of any metropolitan area known today. In Los Angeles, for example, a circle of ten miles radius would cover most, but not all, of the metropolitan area. Outlying communities would not be included but would still suffer damage.

FLASH BURN

There are other damage effects from atomic weapons. At Hiroshima people who were in the open and exposed directly to the light of the bomb were seriously burned. With a hydrogen bomb these effects will be much greater and may extend to an even greater radius than the blast effects. On the other hand, the radiation which produces these burns is very easily absorbed. It is very much like the radiation from the sun, and a shadow or a blanket of smog is a great protection. The same evil-smelling smog blanket which cuts off our sun may, after all, be some protection.

Generally speaking, one would expect the flash burn effects to increase as the square root of the power of the bomb. In other words, for a bomb a thousand times greater than Hiroshima the effects would be expected to extend roughly thirty times as far. At Hiroshima flash burns were severe out to two-thirds of a mile, and without smog absorption or shadows similar burns might be expected out to twenty miles for a hydrogen bomb. Except for a hydrogen bomb exploded at extraordinarily high altitude, such a damage radius would mean that shadows of buildings, trees, bushes, and other objects would be very important in cutting down the direct effect of flash burn.

If you couldn't see the bomb directly, you would expect no effect of flash burn. For a bomb exploded at an elevation of two miles, it would be rather like trying to see Mount Baldy from twenty miles away. Even without atmospheric absorption there would be relatively few spots where some building or other structure would not be in the way.

RADIATION DAMAGE

Atomic bombs, and hydrogen bombs as well, may be expected to release neutrons and penetrating gamma radiation. These particles and rays, however, are absorbed fairly easily in air and will not have an appreciably greater radius of action for a hydrogen bomb than for an ordinary atomic bomb. People who are sufficiently close to be killed by penetrating radiation would very likely be killed in any event by blast effects either direct or indirect. Among those injured, some will definitely show effects of radiation damage.

There has been a great deal of speculation about the radioactive products produced by a hydrogen bomb. The disintegration products produced in the explosion are themselves not radioactive as are the fission products from an atomic bomb. But since an atomic bomb would be needed in order to get the conflagration going, some fission products from that bomb would doubtless be present. But large quantities of radioactivity may be produced from the neutrons which are released in the nuclear conflagration.

If the neutrons released in the hydrogen bomb explosion are absorbed in some material which becomes artificially radioactive, then a very large quantity of this radioactive material will be produced in a big explosion. On the other hand, many of these neutrons might be absorbed in material which would be inactive, and the effects of the radioactivity at least in part avoided. If the neutrons escaped into the air, many of them would be absorbed by nitrogen and, by a nuclear reaction, produce radioactive carbon. This material is most disagreeable as a radioactive contaminant since it has a half-life of many thousands of years.

If such a bomb were exploded under water, however, very few of the neutrons would escape, and most of them would be used to produce radioactive sodium or to activate other elements in sea water, or to produce heavy hydrogen by neutron capture in ordinary hydrogen.

The radioactivity effects of a hydrogen bomb are thus difficult to estimate, since they depend very much on where the bomb is exploded and what material surrounds it. Under conditions in which the largest amount of radioactivity is formed, it would be a dangerous hazard. One of the real scare stories about the effects of radioactivity has postulated the complete explosion of five hundred tons of deuterium, which, while not impossible as far as anyone can say, is stretching probabilities a long way.

From our brief analysis of well-known scientific information it appears that a hydrogen bomb would require a considerable quantity of heavy hydrogen, both deuterium and tritium perhaps, as well as an atomic bomb to set it off and raise the temperature sufficiently so that a nuclear conflagration can exist. Technically, the problem is to figure out how a sizeable fraction of the energy of the heavy hydrogen can be released before the material is cooled too much by emitted radiation or dis-

persed by the explosion. In the stars the radiation is retained because the stellar atmosphere is relatively opaque and there is an enormous difference in temperature between the center and the outside of the star. In a hydrogen bomb there is no such protective layer, and the central problem is to get a large fraction of the energy released while the temperature is still high enough.

Whether this *can* be done will, of course, not be certain until it *has* been done. There are many opinions as to how difficult it may be. Since the President has directed the Atomic Energy Commission to continue with the development, we can assume that this development is regarded as feasible.

IS THE H-BOMB AN EFFECTIVE MILITARY WEAPON?

So much for the technical problems which must be solved in order to develop a hydrogen bomb. While it seems possible that these problems may be solved, whether or not a hydrogen bomb can be developed will be fully determined only when a bomb has been made and exploded. But let us for the moment, assume that the development can be completed. In order that we may try to determine whether or not hydrogen bombs will add materially to our national security, let us try to summarize briefly their effectiveness as military weapons and compare them with atomic bombs already in existence.

If we assume that the hydrogen bomb is a thousand times as powerful as the Hiroshima bomb, it will have a radius for blast damage which is ten times as great. For severe blast damage that means a radius of about ten miles. For flash burn damage, the radius will be theoretically thirty times as great as for the Hiroshima bomb. Absorption and shadow effects will cut this down greatly at the larger distances, so that an effective radius for flash burns for those in the open might be roughly the same as for severe blast damage. Effects of neutrons and hard gamma radiation from the hydrogen bomb would not be expected to extend very much farther than they would for an atomic bomb.

The effects of radioactivity would depend very greatly on where and how the bomb was exploded. Exploded in the air, the effects of radioactivity from a hydrogen bomb would be quickly dispersed, and for long-lived activity, the effects would be almost the same for all parts of the world unless brought down by rain. It might be possible to enhance these radioactive effects by surrounding the bomb with the proper materials and to arrange it so that the active material is deposited near the point of explosion. How successful such an unpleasant operation might be would again depend upon where the bomb was exploded and upon the general climatic conditions which existed at the time. Whether or not our nation would ever want to use radioactive poisons, or a bomb so designed that it would produce them in quantity, is very doubtful. Without trying to answer this question, we see that the effectiveness of radioactive contamination from a hydrogen bomb designed and exploded to enhance that effect seems to be somewhat uncertain and at least in part unpredictable.

We can easily see that a hydrogen bomb is capable of destroying any major city, with the exception perhaps of some of the outlying districts. How does this compare with what could be done with atomic bombs? We have been comparing the hydrogen bomb with the atomic bombs used at Hiroshima, but it has been stated that since the war there have been significant improvements in atomic bombs. These improvements have resulted in more powerful bombs and in a more efficient use of the valuable fissionable material.

Most large cities include many open areas so that a hydrogen bomb would include many square miles whose destruction would contribute in no way to the effectiveness of the bomb. Atomic bombs could presumably be dropped so as to avoid these areas. Furthermore, it was found in the last war that a saturation raid which greatly hampered fire fighting caused damage far beyond the areas of immediate blast effects. Considering all these factors, it seems likely that there is no metropolitan area which could not be thoroughly destroyed with twenty-five atomic bombs. It is more likely that less than ten atomic bombs would be needed to destroy major metropolitan areas and that two bombs would completely paralyze even large cities.

Except for the psychological effects and for the most unpleasant and somewhat unpredictable effects of the radioactivity produced, it appears that a hydrogen bomb which is a thousand times more powerful than an atomic bomb might cause more destruction but would probably not be much more effective than ten atomic bombs. For smaller industrial targets it would not be much more effective than a single atomic bomb.

One begins to wonder just how powerful a military weapon the hydrogen bomb would be. There does not seem to be very much to the statement which has been made by some, that the hydrogen bomb is such a tremendous new weapon that it can completely revolutionize warfare. The hydrogen bomb seems to be a terrible weapon, and certainly large numbers of these bombs could cause untold destruction. Even a relatively small number could deal a major blow to any highly industrialized and centralized country.

THE BIGGER THE BETTER?

But what about the atomic bomb and the damage which might be inflicted with a sizeable stockpile of these weapons? Suppose, just to take a round number, that the United States possessed one thousand atomic bombs of the improved variety. If they could be delivered to military objectives at all, they would go a long way at the rate of ten for a major metropolitan area and perhaps an even smaller number for major cities. With a thousand bombs, there would be a great many for relatively minor military objectives, and I imagine that the military commanders charged with the responsibility of the prosecution of a war would have a hard time figuring out what to do with the last hundred.

It appears that if any nation has as many as a thousand atomic bombs, the world is already in the position where any nation could be blasted thoroughly and completely insofar as bombing alone can be effective. If this is the case, just what additional military use is a hydrogen bomb? For the most part it seems that everyone is fascinated by the idea of "the bigger the better." There are a few examples in the history of the world that should lead us to question this view and not accept it—at least not without argument. We should not forget the dinosaur nor the dodo. We should not forget the battleship, now almost extinct.

Of course it might turn out in a war that it would not be possible to deliver

atomic bombs, or any big bombs, to the targets which the military commanders might want to destroy. If this is the case, and if atomic bombs or any big bombs are a major part of our military preparation, then from the military standpoint, the solution of this problem is vastly more important than deciding exactly what kind of bombs would be carried if they could be delivered.

OUR VULNERABILITY TO THE NEW WEAPON

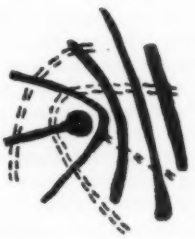
If hydrogen bombs would not add very much to the military effectiveness of the United States, we might ask whether they would add much to Russia's military potential. Here, of course, one gets involved in even more speculation. One is not able to judge whether the Russians have an appreciable chance of delivering the hydrogen bomb by air against the radar defense of this country, which is now being constructed. But even if such a defense is constructed and is reasonably effective, and even if the Russians do not have the same strength of long-range bombers which the United States has, still there is another method of delivery which might be quite effective.

Many of the big metropolitan areas of the United States are located on the seacoast. Into these harbors, or at least reasonably close to them, a hydrogen bomb might easily be brought in the hold of a tramp steamer. While this might not be the most effective place to detonate a hydrogen bomb, it would be a simple method of delivery for a surprise attack. On the other hand, there are practically no Russian cities which could be reached by a similar method of delivery. Another variation might involve the use of relatively small unmanned craft which would run ashore with a hydrogen bomb aboard.

It would thus appear that while the potential effectiveness of a hydrogen bomb in the interior of either the United States or Russia would be about the same for both countries, the hydrogen bomb would be a more effective weapon used against seacoast cities. This means that the hydrogen bomb would be a more effective weapon for the Russians than for the United States.

Some people have argued that if we develop the hydrogen bomb and can really keep its details secret, the Russians will never be able to develop it. There is absolutely no reason at all to believe that this would be the case. Recent experience has shown that the Russians have an atomic energy enterprise adequately developed to make a sizeable atomic explosion. In addition, they probably have fairly detailed information on our atomic weapons work and at least some of the early thoughts on the possibility of a hydrogen bomb as a result of well-known scientific information combined with the blundering indiscretions of some months ago and also from their espionage activity. Given adequate time, they can most surely make a hydrogen bomb if it is possible at all.

From these arguments it appears that hydrogen bombs will not add greatly to the military effectiveness of the United States. How much they would add to Russia's effectiveness against the United States is not exactly clear, but probably somewhat more than they would add to ours. The President's decision to go ahead with the development of the hydrogen bomb created a tremendous stir in the nation. Viewed only from the standpoint of its military effectiveness, there seems to be little reason to attach such great significance to the hydrogen bomb. While it is a terrible weapon, its military effectiveness seems to have been grossly overrated in the mind of the layman.



What is probably much more serious about the hush hush subject of the hydrogen bomb is that here is a weapon about which the average citizen is so ill-informed that he thinks it can save the country from attack. Pumped full of hysteria from Red scares and aggravated by political mud slinging, the average citizen is easily convinced that he can find some security and relief from all of this in the hydrogen bomb which will protect him. The most tragic part is that the hydrogen bomb won't save us, and it isn't even a very good addition to our military potential.

MISTAKEN PUBLIC JUDGMENTS ON VALUE OF BOMB DUE TO EXCESSIVE SECRECY

Here we have the outcome of what can happen in a democracy when decisions of far-reaching national significance are made without public scrutiny of pertinent information. While most of the pertinent information is not secret at all, some of the information which the citizen should have in order to judge whether a national policy is sound, is secret. One of the most important facts which the citizen should have to make a reasonable judgment, is the approximate number of bombs in the United States stockpile. It would be quite surprising if the Russians could not figure this out from the information which they have obtained. Senator McMahon raised the question of making the number of atomic weapons available generally. He was vigorously criticized. As of last spring, not even the members of the Joint Congressional Committee on Atomic Energy knew how many atomic bombs the United States had.

Additional information which would help the citizen to appreciate the relative cost of hydrogen bombs and atomic bombs would be the fissionable material needed to get the hydrogen reaction started and the plutonium equivalent of the tritium to be used. Since neutrons are required to produce either plutonium or tritium, the neutron cost of a hydrogen bomb may be larger than it first appears. These neutrons could, of course, be used to produce additional plutonium, so that there is a very real sacrifice of potential atomic bombs in order to obtain the ingredients for hydrogen bombs. There have been such wide discrepancies in the estimated dollar costs of the hydrogen bomb that the citizen cannot arrive at any sensible conclusion about the money costs.

It is most important in our democracy that our Government be frank and open with its citizens. In a democracy it is only possible to have good government when the citizens are well informed. It is difficult enough for them to become well informed when the information necessary for intelligent judgment of national policy is easily available. When that information is not available, it is impossible. While there may be some cases in which the needed information must be kept secret so that military potential will not be jeopardized, the present use of secrecy far exceeds this minimum limit. These are the methods of an authoritarian government and should be vigorously opposed in our democracy.

The hydrogen bomb and its potential usefulness to the United States as a military weapon is a subject on which the citizens should be much more fully informed. It is a subject of national importance, not only because it is a weapon whose effectiveness has been grossly exaggerated, but it is also one on which we can place relatively little reliance for the future. Quantities of

hydrogen bombs will not contribute very much to the security of the United States. Unfortunately the citizen today believes that they will.

OTHER MILITARY DEVELOPMENTS MORE IMPORTANT FOR SECURITY

If the development of the hydrogen bomb will probably not do much to increase national security, what then might be done which would have importance in this direction? There are probably many answers to this question, but let me just make one suggestion that I am sure is clear to anyone who has thought seriously about the problem.

If the Russians should decide to move into Western Europe, we would immediately be faced with the prospect of fighting a war. Presumably, we could use atomic bombs. It would not be long, however, before we would need a big United States army and supplies not only for that army but also for our allies in Europe. We would have to send these supplies from the United States.

But just how would we get those supplies to Europe? During the past war, on at least two occasions, the Germans came dangerously close to shutting off our supplies to England. This was before the development of the Schnorkel type of submarine which we are told the Russians now have in quantity. It is well known that the Schnorkel submarine, while not absolutely impervious to detection by radar, is most difficult to run down. No method of detection of submarines has been developed which can locate them at any great distance under water. At the moment there is no solution to the problem of hunting down the Schnorkel submarine, and it appears that a determined enemy with adequate bases and submarines could go a long way toward preventing us from delivering men and supplies to Europe. We could presumably deliver a certain amount of material by air, but when it comes to delivering millions of tons, our experience with the Berlin air lift should show us that this is not feasible.

Here is a problem whose solution would contribute greatly to our military strength and therefore to our security. Its solution might even deter the Russians from overrunning Western Europe if they had planned to do so. On this ground it seems to be much more important than the more spectacular hydrogen bomb development.

There are probably a great many more developments which are almost as important as the solution of the problem of anti-submarine warfare. For example, there are the problems of the development of long-range guided missiles. This development is clearly important to military strength. During the last war both the Germans and the Russians were very successful in the tactical use of airplanes with ground troops. New technical developments might be made which would greatly increase the effectiveness of airplanes in tactical use.

It seems very likely that there are many developments related to military strength which may be important for us to pursue. For some of these, as in the case of the development of atomic energy, we may need to choose between weapons and other developments of nuclear power which may have long-range peacetime significance. This long-range peacetime significance may add to our increased industrial strength and thereby make a greater contribution to our long-range strength than the more immediate development of weapons themselves.

NATIONAL POLICY AND THE CITIZEN

At the present time it is most difficult to ascertain how our Government decides what policies to follow regarding national security. High government officials find themselves with advice to pursue this or that development and construct this or that weapon without being very sure how one weapon compares with another. Where the development of a weapon may compete with a long-range industrial development, the problem is still more difficult. The real way to make sure that a reasonable policy is followed is to have those policies and the information on which they are based open for public scrutiny.

Furthermore, although the United States is a rich country, we are not in the position of being able to follow every recommendation that anyone believes will increase our national security.

The citizen must choose insofar as that is possible. Today, if he tries to come to some conclusion about what should be done to increase the national security, he runs up against a high wall of secrecy. He can, of course, take the easy solution and say that these are questions which should be left to the upper echelons of the military establishments to decide. But these questions are so important today that to leave them to the military men to decide is for the citizen essentially to abrogate his basic responsibility. If, in time of peace, decisions on which the future of our country depends are left to any small unrepresentative group, we have gone a long way toward authoritarian government.

The United States has grown to be a strong nation under a constitution which wisely has laid great emphasis upon the importance of free and open discussion. Urged by a large number of people who have fallen for the fallacy that in secrecy there is security, and, I regret, encouraged by many, including eminent scientists who prophesy doom just around the corner, we are dangerously close to abandoning those principles of free speech and open discussion which have made our country great. The democratic system depends on an electorate capable of making intelligent decisions. Our democratic heritage can only be carried on if the citizen has the information with which to make an intelligent decision.

Letter to the Editors

BOULDER, COLORADO

April 1, 1950

GENTLEMEN:

The worst shock I have had since the war was the editorial admission (March 1950) that the *Bulletin* has for four years deliberately suppressed discussion of fusion bombs.

A lack of confidence in democratic processes has been evident on the part of certain scientists on various occasions. But it is indeed dismaying to learn that such thinking has dominated *Bulletin* policy. We do not appear to advantage in criticizing our national Administration for suppressing public information and discussion, when it is disclosed that in our principal publication we have been guilty of the same practice.

The special responsibilities of scientists in our society are sufficiently heavy without our essaying to play God. The damage which has been done to the integrity and prestige of the *Bulletin* will not easily be remedied; but those responsible for its editorial policy can take a step in the right direction by disavowing any intention of again applying such a censorship.

Sincerely,

J. H. RUSH

High Altitude Observatory of Harvard University and University of Colorado

THE CANADIAN ATOMIC ENERGY PROJECT

W. Bennett Lewis

The following two articles describe the atomic energy developments in two countries—Canada and Norway. The author of the first is Director of the Atomic Energy Project at Chalk River, Ontario. Mr. Randers, author of the second article, is head of the Institute for Atomic Energy Studies, part of the Royal Norwegian Council for Scientific and Industrial Research, with headquarters at Oslo. The Bulletin hopes to publish articles on the French and British projects in the near future.

TWO years ago in this *Bulletin*,[1] the story of Canada's participation in atomic energy development was told by Dr. G. C. Laurence from its beginning with his own early experiments with uranium and carbon in 1940 until the summer of 1947. At that time our two uranium-heavy water reactors, together with the laboratories of the project, had been set up on a new site at Chalk River on the south bank of the great Ottawa River 130 miles west of Ottawa. A new village had also been built for the project a few miles farther up the river in one of the most pleasant sites of all those selected for atomic energy development. The village took its name, Deep River, from that forty-mile stretch of the Ottawa River which in many places is some hundreds of feet deep. The site was that of an old log cabin Indian settlement among the pines, birches, and poplars above a beach of most perfect sand facing across the river the Laurentian Hills of the province of Quebec.

Little could be said at that time of the nature of the project. We were then facing a scale of operation beyond all our experience. Low-power heavy water reactors had worked, but the NRX reactor designed to develop 10,000 kilowatts of heat in operation was a step into the unknown. Were we going to be able to keep proper control over the materials in the pile in fluxes of neutrons higher than had been mastered anywhere, with the added difficulty of the intense and unapproachable radioactivity that would be generated in its interior? We were like troops facing their first battle. The campaign has had its triumphs and its set-backs, but in the two years that have passed we have been victorious in the main and now face the future as hardened campaigners, wary and vigilant but with growing confidence.

Before reviewing some of the research achievements of the Canadian project, the reader may wish to be told something of the aims which motivate us. These, of course, can never be fully known, far less can they be set down in writing with any pretense at objectivity. They are compounded of the innate inquisitiveness and curiosity of the research scientist, the desire of man to harness all possible physical power to his use and purposes, the fear of a possible impending resort to force in the struggle for the survival of Western civilization and the knowledge that atomic weapons or nuclear explosions may play a part in this, and the necessity of keeping a technological lead in order to maintain a high standard of living.

The Canadian policy, according to Mr. C. D. Howe, the responsible Government Minister, is directed toward peaceful and constructive applications of atomic energy. This explains the support of a research project which involves the operation of the NRX pile and the consequent production of plutonium, but which stops short of any direct interest in or knowledge of atomic weapon construction.

ATOMIC ENERGY FOR POWER

Most atomic scientists feel confident that nuclear energy will become a significant source of power, but there is a great diversity of opinion as to the time scale involved. There are many successive stages to be realized; some will of necessity cover many years, others may be long or short. The choice of route is also open.

At some stage in the future of the Canadian project we shall doubtless build a reactor which develops power in a usable form. Our present research must lead us toward that day. It seems likely that before that stage is reached one or more experimental reactors will be built advancing the technology. All such reactors are not only costly to construct but also have to be supplied with nuclear fuel; keeping up this supply may be comparably expensive. Suggestions have therefore been made that these experimental reactors should be designed, as far as possible, to act as fuel converters or even as breeders so that the effective cost is kept down to the difference between the cost of the fuel and the value of the product. Operations might even show a profit if costs were lower than in competitive undertakings.

No reactor yet built for high-power operation can claim to have a life expectancy of fifty or, perhaps, even of ten years, and we must expect to have to replace the NRX pile quite possibly in a few years' time.

There seems little doubt that reactor development could proceed much more rapidly if countries were prepared to devote a greater technical effort to this phase of their program independently or in cooperation, and each country must review and evaluate its efforts. These developments form part of a long-range investment. It is to be expected that, even if there are great developments in the economical and efficient use of coal and oil and in means of applying less expensively the much greater flow of energy the earth receives from the sun, the day will come when there will be situations vital to the national economy where the peculiar characteristics of nuclear sources of power make these important. This is setting the lowest valuation on the future of nuclear power. On the other hand, it is possible that its contribution may rise to be equal to or greater than that from coal and oil.

ORGANIZATION OF THE CANADIAN PROJECT

To this background of the nature and purpose of the Canadian Atomic Energy Project some account of the broad organization may be added before describing some of the research achievements.

Under the Atomic Energy Control Act 1946 of Canada, which provides for the control and supervision of the

[1] G. C. Laurence, "Canada's Participation in Atomic Energy Development," *Bulletin*, III (November, 1947), 325.

development, application, and use of atomic energy in Canada, the Atomic Energy Control Board was constituted as the agent of His Majesty.

The Board acts under the general policy direction of the Committee of the Privy Council on Scientific and Industrial Research, of which the Minister of Trade and Commerce, Mr. C. D. Howe, is chairman. A report of the Board has been published annually. The Third Annual Report covers the year April 1948 to March 1949, in which the expenditure was $6,600,000 mostly on the Chalk River Project. It records the excellent operation of the NRX pile in which the highest neutron flux density of any experimental pile has been achieved. It also describes the growing application of radioactive isotopes produced in the pile. It reports the increasing activity in prospecting for uranium and in mining, which are controlled but not financed by the Board.

The Chalk River Project is operated by the National Research Council of Canada on behalf of the Board. Except for the special security requirements, which are kept in conformity with those of the United States and of the United Kingdom, the Atomic Energy Division at Chalk River operates similarly to the other Research Divisions of the National Research Council in Ottawa.

The Atomic Energy Division is organized in four subdivisions for (1) Physics Research, (2) Chemistry and Engineering Research, (3) Biology Research and Health Radiation (Health Physics in United States projects), and (4) Industrial Operations, which include the operation of the NRX pile, the chemical plants, isotope production, and the chemical control laboratories.

THE NEW PARLIAMENTARY COMMITTEE

Until the last session of the Canadian Parliament, general outside knowledge of the operations of the Atomic Energy Control Board, beyond that contained in their annual report, was confined to Cabinet Ministers. In view of the increasing impact of atomic energy on medicine, on research work at universities, and on industry through the use of isotopes, and of the growing significance of the search for and mining of uranium and of the progress of the atomic energy project, a special Parliamentary Committee was set up in the last session to examine the operations of the Atomic Energy Control Board.

This special Parliamentary Committee was composed of members drawn from all parties. It reported in December that for Canada to continue in the forefront in the field of atomic research it will be necessary to press forward the work with vigor. It recommended the continued expansion and development of the project and further recommended that the Government undertake the expansion of the present facilities by the construction of an additional reactor and such research equipment as may be required.

RESEARCH PROGRESS

The NRX pile is primarily a research tool, and there are many researches in many fields for which its copious supply of neutrons is most valuable. Not only can it be used for experiments of direct application to atomic energy development, but it also contributes to the advance of knowledge in the fundamental fields of nuclear physics, radioactive chemistry, radiation chemistry, and biology.

Although an unprecedented number of laboratories are working on the attempt to unravel the laws governing the structure of atomic nuclei, the special facilities at Chalk River have enabled us to make some contributions worthy of mention. Our knowledge of the neutron itself has been changed and improved. In 1948, R. E. Bell and L. G. Elliott[2] were surprised to find that when neutrons were captured by the hydrogen in paraffin to form deuterium, the excess energy radiated as gamma-radiation was about 50 keV. more than expected. In the eight years of normal research which followed the discovery of the neutron in 1932, it had been established that the neutron was slightly heavier than that other combination of proton and electron, the hydrogen atom. It was thought that this difference of mass was known with an accuracy of about 1 per cent, but this new result raised the difference by 7 per cent. Naturally, this evoked some interest, and in 1949 at least a score of papers reporting further relevant measurements had been published from widely spread laboratories. All serve to confirm the accuracy of Bell and Elliott's observations, and they themselves have confirmed and refined their measurements.

Moreover, since the neutron is heavier than the hydrogen atom it should be able to transform into a proton and electron with the release of some energy; in other words, the free neutron should be a radioactive beta-ray emitter. From analogy with known beta-emitters the neutron half-life should be about twenty minutes. This radioactive decay of the neutron has been confirmed in separate experiments by A. H. Snell[3] at Oak Ridge and J. M. Robson[4] at Chalk River. In Robson's experiments the protons resulting from the decay of the neutrons were identified by the ratio of their charge to their mass. From the proton counting rate of about 100 per minute, the geometry of the apparatus, and the thermal neutron flux of $2 \times 10^9/cm^2/sec.$ in the beam emerging from the pile, the half-life of the free neutron is deduced to lie between 9 and 20 minutes.

The general method of disturbing a nucleus by the injection of a neutron reveals much information on the possible energy levels of the resulting nucleus. These researches are usually described as observations of the gamma-rays arising from neutron capture. The above-mentioned experiment of Bell and Elliott was part of such a study. Another interesting observation in the series[5] was that the 478.5 keV. gamma-ray arising from the B^{10}(n, alpha) $Li^{7*} \rightarrow Li^7 + j$ reaction was not a sharp spectral line. The energy breadth is explained as due to the Doppler effect from the motion of the swiftly moving excited Li^{7*} nucleus. Moreover, the breadth can be varied by arresting the motion of the Li^{7*} nucleus in solids of different density. In iron-boride, which is relatively dense, the particles were stopped so quickly that most of the gamma-ray emission took place after the Li^{7*} nuclei had been stopped and the gamma-rays then formed a sharp spectral line. From a detailed study of this it was deduced that the half-life of Li^{7*} before gamma-ray emission was 0.75×10^{-13} sec., a useful confirmation of general ideas of the duration of such nuclear processes.

Much of the gamma-radiation following the capture of neutrons lies in the energy range 3 to 10 MeV. This is a convenient range to study by observing the pairs of positive and negative electrons produced in a heavy element target by the j radiation. The supply of neutrons available has proved sufficient to observe readily and rapidly the radiations from elements with very low capture cross-sections such as beryllium, carbon, bismuth, and lead. This research led by B. B. Kinsey[6] is revealing much detailed and exact information about the energy levels which can be excited in nuclei and should lead to a better understanding of nuclear structure.

[2] R. E. Bell and L. G. Elliott, *Physical Review*, 74 (1948), 1552, and in publication.

[3] A. H. Snell and L. C. Miller, *Physical Review*, 74 (1948), 1240A, and in publication.

[4] J. M. Robson, *Physical Review*, 77 (1950), 747A, and in publication.

[5] L. G. Elliott and R. E. Bell, *Physical Review*, 76 (1949), 168A.

[6] B. B. Kinsey, G. A. Bartholomew, and W. H. Walker, *Physical Review*, 77 (1950), 723, and in publication.

DEVELOPMENT IN INSTRUMENTATION

The existence of a steady source of neutrons operating twenty-four hours per day has stimulated developments in instrumentation. Instruments must be reliable in continuous operation, automatic for unattended operation, and must incorporate the maximum discrimination and resolution obtainable. Electronic equipment may be devised to meet these requirements, but up to 1947 at Chalk River as in other atomic energy laboratories, only one or two good instruments were to be found here and there. No organized and concerted drive had been made to bring the standard of engineering of electronic equipment up to that attained in radar and communications. The problems were different; in particular the significance of stray impulses or irregularities in background level is much greater than in radar and communications. It was not, therefore, sufficient to accept the techniques and standards developed in those fields; it was necessary to develop new techniques and standards to bring the engineering to a comparable level. In part this has now been accomplished, but there is still remarkably little unity and solidarity between the many institutions applying electronics in radioactive and similar work. Very high standards have been set and achieved with the new instruments produced for us by the electronics industry in Canada.

Much use has been made of our "kicksorters"[7] or pulse amplitude analyzers. These are electronic counting instruments which, when supplied with pulses of duration less than a microsecond and of various amplitudes, will sort them according to size in up to thirty separate counting channels. Used with proportional chambers, which produce pulses proportional to the ionization from the registering particle, the kicksorter has shown[8] that the proportional chamber itself has a precision of operation beyond that expected on any satisfactory theory yet proposed. It proved possible[9] to make a fair measurement of electrons of only 250 volts energy by the ionization they produce. This technique has been applied to delineate the energy distribution of the beta-rays from the radioactive disintegration of tritium,[10] the maximum energy of which is only 18.7 keV.

[7] C. H. Westcott and G. C. Hanna, *Review of Scientific Instruments*, 20 (1949), 181.

[8] G. C. Hanna, D. H. W. Kirkwood, and B. Pontecorvo, *Physical Review*, 75 (1949), 985.

[9] B. Pontecorvo, D. H. W. Kirkwood, and G. C. Hanna, *Physical Review*, 75 (1949), 982.

[10] G. C. Hanna and B. Pontecorvo, *Physical Review*, 75 (1949), 983.

Kicksorters have also been used by the chemists for the rapid analysis of mixtures of alpha-ray emitters occurring in the isotopes of the transuranic elements.

RADIATION CHEMISTRY

The subject of radiation chemistry, which deals with chemical effects resulting from radiations, is probably destined to play a considerable part in the future development of atomic energy. At present many of the fundamentals are still to be established. At Chalk River the quantitative effects produced in dilute aqueous solutions are being studied, and some interesting results have been obtained.[11] It appears that certain oxidations take place quantitatively and independent of concentration even in concentrations as low as one part in a million in molecular proportions. This means that in water the energy derived from the radiation by the water itself is dissipated always through this process, even if the molecules where such action can take place, are sparsely distributed. Trace amounts of dissolved oxygen or hydrogen can have marked and quantitatively reproducible effects. It appears there is much order involved in the manner of degradation of the radiation energy.

These are just a few of the highlights of the fundamental research being carried out at Chalk River. Other researches include studies of the rarer modes of nuclear fission,[12] transmutations produced by tritons accelerated to 220 keV.,[13] decay products of mesons,[14] studies of nuclear cross-sections for neutron capture of radioactive[15] as well as stable nuclei, tracer methods for studying diffusion in the solid state and critical temperatures revealed by such studies, and mutations of bacteria[16] produced by radiation and their characteristics compared with other mutations. A complete list would be tedious and out of place in such a review. Moreover, the objective of the Atomic Energy Project is to keep the fields of science, which we may need in atomic energy development, alive somewhere in Canada and not necessarily at Chalk River itself. We work closely with the mass-spectrometer group at McMaster University and have links with many research groups at universities throughout Canada.

[11] F. H. Krenz and H. A. Dewhurst, *Journal of Chemistry and Physics*, 17 (1949), 1337.

[12] K. W. Allen and J. T. Dewan, *Physical Review*, 75 (1949), 337A; J. T. Dewan and K. W. Allen, *Physical Review*, 76 (1949), 181A; D. C. Brunton and G. C. Hanna, *Physical Review*, 75 (1949), 990; D. C. Brunton and W. B. Thompson, *Physical Review*, 76 (1949), 848A; D. C. Brunton, *Physical Review*, 76 (1949), 1798.

[13] K. W. Allen, J. H. Sanders, T. P. Pepper, and E. Almqvist, *Bulletin of the American Physical Society* (for Washington D.C. meeting), April 1950.

[14] E. P. Hincks and B. Pontecorvo, *Physical Review*, 75 (1949), 698, and in publication.

[15] L. Yaffe, B. W. Sargent, M. Kirsch, S. Standil, Jean M. Grunlund, *Physical Review*, 76 (1949), 617.

[16] H. B. Newcombe and Grace W. Scott, *Genetics*, 34 (1949), 475.

PILE-PRODUCED ISOTOPES

The Atomic Energy Project also supplies pile-produced isotopes. The applications of isotopes to scientific researches and to industrial processes are rapidly increasing in Canada as elsewhere. Moreover, the high neutron flux available in the NRX pile makes it possible to produce certain radioactive isotopes in much higher specific activity than is possible in other reactors. This is important, for example, in the case of Cobalt 60, which can be produced by the direct irradiation of cobalt metal in the pile. The saturation activity produced by many years' irradiation would be as high as 60 curies per gram of metal, and an activity one tenth of this can be achieved in a few months' irradiation. Cobalt 60 emits penetrating gamma radiation and is finding uses in place of radium and X-rays in industry for taking radiographs of welded joints, castings, and other machine parts. For such purposes the source of radiation should be small in physical size, so the high specific activity is an advantage.

There appears to be a possibility of developing Cobalt 60 sources of 1,000 curies or more. If satisfactory means of handling these can be developed, they might be applied to provide beams of gamma radiation replacing high-energy X-ray sources for therapeutic irradiations.

The facilities of the NRX pile are more than sufficient to produce all the radioactive isotopes required for tracer experiments in Canada and for work in radio-chemistry.

The export of isotopes from Canada is governed by regulations similar to those in force in the United States, but special arrangements have been made to market Cobalt 60 for general purposes in the United States and elsewhere.

CONCLUSION

From this account it will be apparent that our achievement has been in fundamental research and in the acquisition of the techniques necessary to handle the large amounts of radioactive substances made by the operation of a reactor of moderately high power. This provides us with a firm basis of experience on which future undertakings in atomic energy development can be based with some confidence.

PLANNING FOR ATOMIC PHYSICS IN NORWAY

Gunnar Randers

Why does Norway want to build a pile? This question often arises in discussions with scientists from abroad.

It seems to me that the question is better put the other way round: Why should Norway *not* want to build a pile?

The reason, which for most people seems to weigh heavily against building a pile, is the cost. Everything having to do with atomic energy has come to be considered as overwhelmingly expensive—at any rate, beyond the reach of a small country with about three million inhabitants.

This impression of overwhelming cost is, to a certain extent, a remnant from the first reports from the USA and England about their wartime projects. These were organized and carried out with a complete disregard for cost and under very special circumstances.

It is still true that a plutonium plant of the present type probably is beyond the reach of a small country, even if the cost does not approach the cost of the American wartime plants. However, a nuclear reactor is not necessarily identical with a plutonium production plant. A nuclear reactor is also an instrument for scientific research, without which scientists today are handicapped.

One of the most important and necessary incentives for a scientist is the knowledge that there is no branch of his field from which he is cut off because of lack of facilities. For several years it has been clear to most physicists, chemists, and biologists that work with isotopes is going to be a necessary part of their research. It is also clear that neutron physics cannot be carried on effectively without the intense beam provided only by a pile.

Finally, there is the belief that atomic energy may in due time play the important role which publicity ascribed to it as early as 1945. If nothing else, the desire for specialists capable of understanding the developments in other countries seems sufficient justification for the building of a nuclear reactor.

THE REACTOR AT KJELLER

The reactor under construction in Norway is a heavy-water uranium-oxide reactor. It is designed for an energy of the order of magnitude of 100 kw. The cooling is achieved by circulating the heavy water through a heat exchanger. The reactor will be equipped with completely automatic controls. This may not be necessary for the type of pile in question, but it is one of the things we want to do to gain experience. The uranium, the heavy water, the aluminum tanks, the tubes, etc., will all be produced in Norway.

The reactor will be located at Kjeller, fifteen miles outside Oslo, near the existing physics and chemistry laboratories of the Defense Research Establishment.

THE INSTITUTE FOR ATOMIC ENERGY STUDIES

The planning and the construction of the pile has been placed under a newly created institute, called the Institute for Atomic Energy Studies. It is part of the Royal Norwegian Council for Scientific and Industrial Research, and is a purely civilian institute. As a financial unit, the Institute for Atomic Energy Studies is semi-state and semi-industrial, in that the state and the industrial concern, Norsk Hydro, support it on a fifty-fifty basis. It is run by a board of six members from science and industry, with Mr. Gunnar Randers as chairman, and Mr. Odd Dahl from Bergen as vice-chairman.

At present the Institute has a department for electronics in Bergen, a mining department in Evje (in the southern part of Norway), and the main laboratories and offices at Oslo. The building for the pile has been erected. The concrete shielding is partly finished. The laboratory for chemical analysis is gradually being equipped, and so are the physics laboratories. Work with refining of the uranium ore is being carried out at different places in existing institutions, as well as in the institute's own laboratories.

Other instruments for nuclear physics are being built both at the Institute for Atomic Energy Studies and at our universities. At the pile site smaller instruments like mass spectrographs, beta spectrographs, X-ray spectrographs, etc., are under construction. In Bergen a nuclear high voltage laboratory is growing up as a common effort of the Oslo and Bergen group. A new open air Van de Graaff has been erected and runs now with a voltage of 1.8 million volts. A betatron for about 50 million volts is the next project. It should be finished during 1950. These two machines are housed in a new building, constructed partially underground.

At the University in Oslo, a pressure generator for 5 million volts is expected to be completed during 1950. A similar generator is planned at the Technical University in Trondheim.

THE VALUE OF THE PROJECT

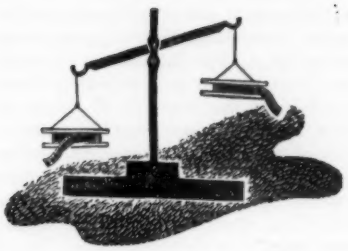
To American physicists, surrounded by millions of volts wherever they turn, it may seem unimportant and perhaps a waste of energy to build all this medium-sized equipment, when bigger things are being made all the time at other places. To the physicists involved it is not as simple as that. First of all, there is more than enough research for which medium-sized equipment serves as well as giant equipment. Also, the physicists working with the construction will personally learn as much from this sort of equipment as from bigger things. Finally, considering Norway, Sweden, and Denmark together, the total sum of equipment accessible in this area is gradually growing into something which is quite respectable.

As most people realize, the fact that a nation has a large population does not necessarily mean that it produces better individuals. What sometimes makes it appear this way is that the big nations can more easily help individuals realize their abilities by providing them with education and tools. It is obvious that any country which does not try to provide facilities for its scientists will lose its best men, and cannot then expect to remain on an equal footing with countries which accumulate not only their own, but also other nations' top scientists. An undertaking like the Norwegian atomic energy project is therefore not a luxury nor an amusing game for the scientists, but one of the many necessary efforts which a nation today must make to secure its existence in the long run.

ON NEGOTIATING WITH THE RUSSIANS

Hans J. Morgenthau

The following article is the third in a series on atomic weapons and foreign policy written by Professor Morgenthau, of the Department of Political Science at the University of Chicago. His earlier articles appeared in the January and March issues of the Bulletin.



IN A NEWSPAPER column published some time ago, Edgar Ansel Mowrer described American foreign policy as being "founded on two pillars —stabilize the non-Communist world economically and politically, and back up freedom-loving peoples with the promise that, if attacked, the United States will fight with them." After stating that unless the American people are ready for both, they will not be able to stop Stalin, Mr. Mowrer continued: "The American Administration believes that many Americans are unwilling to see the situation as it is. Otherwise, a great political scientist like Hans Morgenthau of the University of Chicago and a great newspaperman like Walter Lippmann could not continue to talk about negotiating a settlement of Europe with the Kremlin. They would accept the fact that no settlement is possible—at least not so long as any soft spots remain in the world which Stalin can penetrate by intrigue, by threats or by Red Army violence."

The fact of the matter is that I do not know whether a negotiated settlement with the Soviet Union is possible. I do know, however, that no such attempt at a negotiated settlement has been made; instead we have wasted our time with polemics over isolated secondary issues which must remain insoluble as long as the basic issues remain unsettled. I also know that, in view of the present and foreseeable distribution of power between the United States and the Soviet Union, the choice before the world is between negotiated settlement and war, that is, universal destruction. I finally know that no nation can survive the ordeal of a third world war, if it can survive it at all, without being convinced in its collective conscience that it has done everything humanly possible to preserve peace. It is for these reasons that I deem it worth while and even imperative to consider seriously the possibility of a negotiated settlement with the Soviet Union.

THE THREE ARGUMENTS AGAINST NEGOTIATION

Three kinds of arguments are generally advanced in support of the thesis that it is impossible to negotiate with the Russians.

1. The Russians keep agreements only so long as it is in their interest to keep them and break them at will when they think it advantageous to do so.

2. In order to bargain successfully with the Russians, one has to be strong; for it is only the irresistible logic of "situations of fact" which will make the Russians keep their bargains.

3. The objective for which the Russians are willing to negotiate, i.e., the division of the world into spheres of influence, is unacceptable to the United States.

The first of these arguments is derived from undeniable facts, but it is irrelevant for the issue under consideration. The second argument is correct as a general proposition, but debatable in its practical application to the current problems of American foreign policy. The third of these arguments goes to the core of the matter. With the soundness of this argument the negative attitude toward negotiations with the Soviet Union stands and falls. In the terms in which it is generally formulated it is hard to see how its soundness can be defended.

SOVIET ATTITUDE TOWARD INTERNATIONAL AGREEMENTS

It is, of course, undeniable that since the end of hostilities, and even before, the Soviet Union has violated international agreements which it thought advantageous to violate, and it matters little whether there have been about forty such violations, as our official count has it, or more or less. It is also undeniable that the Russians have engaged in treaty violations with a cynical disregard for the niceties of diplomatic intercourse, with a complete unconcern for the sensibilities of the other side, which more subtle diplomats might well have spared without sacrifice of their political objectives, and, finally, with a brutal frankness which was bound to come as a shock to those who like to think of the moral standards of international politics in terms of the ideals of a well-behaved, law-abiding business community. Yet while it is true that the Russians have violated those agreements which to keep they did not deem to be in their interest, it is also true that they have kept those agreements which they thought it to be in their interest to keep. For this we have the testimony of Mr. Churchill, who on January 23, 1948, said in the House of Commons: "It is idle to reason or argue with the Communists. It is, however, possible to deal with them on a fair, realistic basis, and, in my experience, they will keep their bargains as long as it is in their interest to do so, which might, in this grave matter, be a long time, once things were settled."

TREATY OBSERVANCE CONTINGENT UPON NATIONAL INTEREST

If the foregoing statement of the Russian attitude toward international agreements is correct, then the Russian attitude differs only in manner and form, but not in substance from the attitude which all great powers have traditionally taken with regard to international agreements. That is to say, the road which the great powers

have travelled throughout history is strewn with the broken fragments of solemn promises and scraps of torn paper inscribed with treaty stipulations. "Perfidious Albion" has become a byword summarizing the experience of centuries with the fickleness of British "balance of power" policies and with British imperialism's disregard for legal scruples. The faithlessness of Italian diplomacy has been proverbial from the days of the Republic of Venice to Cavour. And it was that greatest of Italian statesmen who said, in looking back on his public life: "If we had done for ourselves what we have done for Italy, what scoundrels we would have been."

From that iron law of international politics—that legal obligations must yield to the national interest—no nation has ever been completely immune. The self-righteousness of a blind nationalism may at times flatter itself on such immunity, and the needs of propaganda may make it necessary to assume it. Yet in truth there are but two differences among nations concerning the respect for legal obligations, one affecting the manner of getting rid of burdensome obligations, the other affecting the need for doing so. Certain nations have a flair for throwing burdensome obligations overboard in an elegant, unobtrusive fashion or for chiseling them away with the fine tools of legal misinterpretation; the latter method French diplomacy has developed into an art. Other nations, such as Germany and Russia, have taken to the disconcerting habit of announcing to all the world that a certain inconvenient treaty has become "a scrap of paper," as did the German Chancellor in August 1914, when he denounced the treaty guaranteeing the neutrality of Belgium, and of throwing the scraps in the face of the world.

As concerns the need to violate treaty obligations, a distinction can be drawn between nations pursuing a policy of the *status quo* and those pursuing a policy of expansion. The former, primarily interested in preserving the existing distribution of power, especially with regard to territory, are most likely to formulate their policies in the legalistic terms of the existing treaties which embody the territorial *status quo*. Thus the *status quo* policies of France in the interwar period were formulated in terms of respect for the provisions of the Treaty of Versailles and of the Covenant of the League of Nations. On the other hand, nations pursuing expansionist policies will disregard legal obligations which stand in the way of their expansionist aims. This is what France, for instance, did under the two Napoleons.

The truth of the matter has well been summarized in a treatise on *Sanctions and Treaty Enforcement* by Professor Payson S. Wild, former Dean of the Harvard Graduate School of Arts and Sciences and at present Vice-President and Dean of the Faculties of Northwestern University. "The more one goes into the topic of treaty sanctions at present, however, the more is he puzzled concerning their value and usefulness. It is true that treaty observance is important, but is it not also true that, in a world where nationalism is rampant, only those treaties which states consider to be to their advantage will be kept regardless of special sanctions, and that where treaties stand in the way of what Professor Schuman has termed the 'politics of power,' no amount of implementation or coercion on paper will deter a violator? No state thinks of infringing upon the provisions of the International Postal Convention, while the whole League Covenant, the Nine Power Treaty and the Pact of Paris did not stop Japan in Manchuria. In other words, is it not the nature of the treaty rather than the nature of the sanctions which determines compliance? Such a question goes back to the international standard of justice discussed earlier as a sanction, and it seems safe to say that only insofar as all signatory states firmly believe a treaty to be a 'good' one, a 'just' one or a 'useful' one is it really sanctioned, and that it is of small avail to attempt to pin sanctions upon treaties which are apt to run athwart the national policies of powerful states."

In sum, the real issue which is posed by the frequent violations of international agreements by the Soviet Union is not whether or not the Soviet Government is inherently, by some kind of natural depravity, as it were, oblivious of legal obligations, but whether or not the conception of the Russian national interest which gave rise to those violations of international agreements is compatible with the national interest of the United States. This is not a contest between virtue and vice, defined in the terms of a lawyer's code of conduct, but a clash between the foreign policies of two great powers pursuing apparently incompatible objectives. The test, therefore, of whether a negotiated settlement with the Soviet Union is possible is to be sought not in the lawyer's concern with legal obligations, but in the statesman's concern with the reconciliation of apparently irreconcilable national interests.

STRENGTH ONE PILLAR OF PEACE

It is, then, on the level of policy and not of law that the issue must be joined. What are the preconditions for a political settlement which has a chance to last, and do these preconditions exist in the relations between the United States and the Soviet Union? To the first of these questions Secretary of State Acheson, at his news conference of February 12, 1950, has given an answer, admirable for the lucidity of its presentation and for its intellectual grasp of at least one side of the political problem which is posed by the question. The gist of Mr. Acheson's remarks is the distinction between paper agreements and agreements "which register the existing facts." The former are useless, for they will be broken whenever it is in the interest of one or the other of the contracting parties to do so. The latter are useful, for to observe them is in the interest of the parties concerned. In the words of Mr. Acheson, "it is not a matter of agreement but a matter of registering the existence of a situation." "Thus what I want to stress here is that agreements with the Soviet Union are useful when those agreements register or record an existing situation of fact, but that otherwise they are not of much use. So it has been our basic policy to build situations which will extend the area of possible agreement, that is, to create strength instead of the weakness which exists in many quarters."

This analysis is unexceptionable as far as it goes, and so are the examples of the Berlin blockade, of Greece, Turkey, and China, with which the Secretary of State supported his thesis. Yet these examples need not be limited to the postwar relations between the United States and the Soviet Union. For it is a general law of international politics, applicable to all nations at all times, that only those agreements have a chance to be effective and to last which express in legal terms the identical or complementary interests of the contracting parties, and that they last only as long as their terms coincide with those interests. No period of recorded history has provided such overwhelming negative proof for the generality of that law as the interwar period. This was the period which has been appropriately called one of "pactomania," when every unsolved international problem, from war in general to the relations of two nations in particular, called forth an international agreement proclaiming in legal terms the "solution" of the problem. All these agree-

ments, from the Briand-Kellogg Pact to the Locarno Treaties and the innumerable Arbitration, Friendship, and Non-Aggression agreements, left the problem exactly where they had found it. Yet they created, especially in the legalistically minded statesmen and masses of the West, the illusion of security and false hopes which, undismayed by ever renewed disappointments, were carried from one international conference and the paper agreement concluding it to the next.

THE DEBACLE OF THE YALTA AGREEMENT

Of such international agreements which confound a legal promise with a situation of fact, probably the most destructive for the cause of peace in our time is the Yalta Agreement of 1945 with regard to Eastern Europe. The military agreements between the Western Allies and the Soviet Union and, more particularly, the Western strategy providing for the invasion of Europe through France rather than through the Balkans had made, as a matter of military fact, all of Eastern Europe, Central Europe to the Elbe, and all of the Balkans, with the exception of Greece, a Russian sphere of influence. This situation of fact, the Western statesmen were bound to find as threatening to the vital interests of their countries as a similar situation had appeared to the England of Castlereagh and Canning in the years after 1815. Yet, in contrast to the superb statesmanship of these ministers, the Western negotiators at Yalta endeavored to rectify a disagreeable and threatening situation of fact, which, incidentally, had been in a good part of their own making, by a paper agreement in which the Soviet Union promised to give the Western Allies the opportunity to exercise some influence in the countries of Eastern Europe and the Balkans through the instrumentality of liberal, democratic regimes to be established in those countries. The moral indignation at the speedy violation of those promises, which has not yet abated in the Western world, is humanly understandable, while such violation can hardly surprise those who believe in the soundness of Mr. Acheson's principle. For this is what is likely to happen if a situation of fact is to be modified by legal stipulations which are themselves divorced from the existing situation of fact. If the Western Allies wanted to retain some influence east of the Elbe and north of Greece, they should not have allowed the Red Army to advance as far as they did. Once the Red Army had created a situation of fact which made the Soviet political domination of Eastern and part of Central Europe and of the Balkans inevitable, the Western nations had only two rational methods at their disposal for modifying the extent and character of that political domination: to create a new situation of fact either by forcing or by persuading the Red Army to retreat. To expect the same political results from political promises not accompanied by any change in the situation of fact was an illusion sure to be followed by a disappointment for which we might well blame our political immaturity rather than the malevolence of the Russians.

While thus the soundness of Mr. Acheson's principle cannot be doubted, it gives rise to two questions, one concerning its application to the actual relations between the United States and the Soviet Union, the other concerning its completeness.

THE PROBLEM OF TIMING

In its application to the actual relations between the United States and the Soviet Union, Mr. Acheson's principle forces us to consider how strong the United States is in comparison with the Soviet Union and how strong it is likely to be in the future. Mr. Acheson's practical conclusions that at present it is impossible to negotiate with the Russians because we are not strong enough is sound only under the assumption that in the future we will be stronger in relation to the Soviet Union than we are now, and that, hence, the chances for a favorable settlement with the Russians, that is, our bargaining position, will be better in the future. In other words, the problem which confronts us here is that of timing the negotiations with the Soviet Union. It is one thing to state the general conditions without which negotiations with the Soviet Union have no chance to succeed. It is quite another to assert that these conditions do not exist at present but will exist in the future. While we agree readily with the former statement, we must question the soundness of the latter assertion.

To speak first of things that are certain because they are past history, there can be no doubt that thus far the policy of waiting has not improved the bargaining position of the United States. Up to September 23, 1949, when President Truman announced that an atomic explosion had occurred on Russian soil, the United States, secure in the monopoly of the atomic bomb for a number of years to come, thought it should postpone negotiations with the Soviet Union until the military and economic recovery of the nations of Western Europe had restored the balance of power in Europe. In retrospect it is obvious, in view of the disappearance of the American monopoly of the atomic bomb and the deteriorating situation in Asia, that our bargaining position vis-à-vis the Soviet Union was better a year or two years ago than it is now; that is, we were then considerably stronger in comparison with the Soviet Union than we are now. As so eminent an observer of the international scene as Winston Churchill put it, in the House of Commons on December 19, 1948: "Finally, I wish to say one word—and it shall be only a very brief one—about the greatest topic of all which overhangs our minds, our relations with Soviet Russia. I have frequently advised that we should endeavour to reach a settlement with Russia on fundamental, outstanding questions before they have the atomic bomb as well as the Americans. I believe that in this resides the best hope of avoiding a third world war. I wish to make it clear—and this is the principal reason why I refer to this matter in the Debate—that I have never attempted to suggest the timing of such a solemn and grave negotiation. I have not the official knowledge necessary to form an opinion about that."

Our policy of waiting for a better bargaining position was certainly mistaken in the past. Is our bargaining position likely to be better a year from now when we might well be worse off in Asia than we are now? Is it likely to be better two years from now when the Soviet Union will have a stockpile of atomic bombs? Is it likely to be better three years from now when the Soviet Union might well be in the possession of hydrogen bombs? All political predictions are, of course, derived from hunches which may or may not come true, and timing is the most delicate of diplomatic tasks. Spectacular events, unforeseen and unforeseeable, may upset the most careful calculations of the experts, yet in their blind and impartial ways they may upset the calculations of either side. This much, however, can be said with certainty—that any considerable change of the distribution of power in favor of the United States would require a national effort, tantamount to sacrifices in the amenities of life enjoyed by the American people infinitely greater than anything ever accepted as politically tolerable in times of peace. Under great and in-

spiring leadership, who could doubt that the American people would rise to the occasion in times of peace as they have in times of war? Given a regime which is painfully reminiscent of the administration of Calvin Coolidge—only it is a Coolidge left, instead of right, of center—how can one expect that enormous national effort which alone would be capable of redressing the balance of power in relation to the Soviet Union?

Nor are those all the risks which waiting incurs. What we have said thus far assumes that the question of peace or war, that is, of negotiated settlement or war, is and will remain under the control of the two great powers which would be the main protagonists in war as they are the main opponents in peace. This, however, is not so. Here again, we can let the greatest of contemporary actors on, and observers of, the international scene speak for us. On January 23, 1948, Winston Churchill had this to say in the House of Commons: "I will only venture now to say that there seems to me to be very real danger in going on drifting too long. I believe that the best chance of preventing a war is to bring matters to a head and come to a settlement with the Soviet Government before it is too late. This would imply that the Western democracies, who should, of course, seek unity among themselves at the earliest moment, would take the initiative in asking the Soviet for a settlement. . . . We may be absolutely sure that the present situation cannot last. . . . There are very grave dangers—that is all I am going to say today—in letting everything run on and pile up until something happens, and it passes, all of a sudden, out of your control."

There are so many inflamed points of contact between the East and the West that only an optimism, uninformed by past experience and oblivious to the portents of the present, could rest secure in the expectation that the flames of war might not break out at any such point at any time, without anybody wanting it but without anybody being able to prevent it. There are today any number of candidates for the role which Serbia played in bringing about the First World War: to light the match which sets the fire to consume the flimsy structure of great power relations. Failure of nerve or recklessness in Berlin, at one of the borders of Yugoslavia, at the frontiers of Hong Kong, could start a chain of events which soon would pass out of the control of all concerned. And what is a threat to the peace today will be a still greater threat a year, or two, or three years from now, when the countries which are the prizes of the power contest between the East and the West will either have grown stronger, as will Germany, and will therefore be able to play a more active role in international affairs, or may well have grown weaker, as may the countries of Southeast Asia, and will thus have become a more tempting object for internal subversion and foreign conquest.

CONCURRENCE OF INTERESTS—THE OTHER PILLAR OF PEACE

We have said that Mr. Acheson's principle, sound in itself, gives rise to two questions, one concerning its application to the present world situation, the other concerning its completeness. We have now to say a word about this second point. A situation of fact favorable to a negotiated settlement consists of two elements: strength and conflicting interests capable of reconciliation. Strength is an indispensable prerequisite for successful negotiation, but it is not the only one and probably not even the most important one. The pacifying function of negotiated settlements consists in the reconciliation of apparently incompatible interests. "The only bond of union that endures" among nations is, in the words of Lord Salisbury, "the absence of all clashing interests." There are situations where interests inevitably clash and which therefore cannot be settled peacefully.

Between a Napoleon or a Hitler and the prospective victims of their conquests there is no common ground for a peaceful settlement except submission to the will of the conqueror. It is the supreme test of statesmanship whether it is able to assess correctly the chances for peaceful settlement by ascertaining the vital interests of the opposing nations and their relation to each other. Concessions born of the false belief that conflicting interests are actually compatible is appeasement. The refusal to negotiate in the false conviction that conflicting interests are irreconcilable is to court a needless war. The task of ascertaining what one's own nation needs and wants in order to be secure, and what the other nation needs and wants in order to be secure, and whether there is ineluctable conflict or the possibility of accommodation between these needs and wants—this task is an intellectual one, the highest of those constructive tasks which the Hamiltons, the Pitts, the Cannings, the Disraelis, and the Churchills face and solve, and whose very existence is ignored by the amateurs. If American foreign policy consisted of nothing but the accumulation of strength at the points of conflict with the Soviet Union, Mr. Acheson's principle would be no more than a rationalization of the cold war, of the continuation of the armaments race in the hope that time is on our side and that in due course of time we will be able to impose a settlement favorable to ourselves upon the Soviet Union. Such a policy would fall far short of constructive statesmanship; it could hardly be called statesmanship at all, for it would be concerned with the military and political preconditions of successful diplomacy rather than with diplomacy itself.

SPHERES OF INFLUENCE—MEETING POINT OF COMPETING POWERS

The traditional method of settling peacefully a conflict between two nations with respect to a piece of territory which belongs to neither but in which both have an interest has been to divide the territory into spheres of influence and thus to satisfy, at least in part, the interests of both sides. All the great peace settlements which lasted because they were able to create identical or complementary interests among the contracting parties have used spheres of influence as one of their instruments. The Treaty of Vienna of 1815 did so for the relations between Russia and the other European nations in Eastern Europe; the Congress of Berlin of 1878 did so with regard to the relations between Great Britain and Russia in the Balkans and the Near East; the same was done in the Franco-British Agreement of 1904 for Africa, and in the Russo-British Agreement of 1907 for Asia. In 1944, Churchill and Stalin, on the former's suggestion, concluded a spheres of influence agreement with regard to the Balkans whose duration was, however, limited to three months, primarily because of Mr. Cor-

dell Hull's opposition to spheres of influence as a matter of principle.

OFFICIAL ARGUMENTS AGAINST SPHERES OF INFLUENCE

Since the breakdown of the Yalta Agreement, the Soviet Union has made numerous proposals for the division of the world into two gigantic spheres of influence, one dominated by the Soviet Union, from which Western influence would be excluded, the other free from Soviet domination and infiltration and under the dominating influence, to a greater or lesser extent, of the United States. While these proposals have never been officially acknowledged by the United States, they have been from time to time referred to by reporters and columnists. Those who have mentioned them have generally assumed—Mr. Walter Lippmann being the most notable exception—that the very idea of such an agreement must *a priori* be rejected. A dispatch in the *New York Times* of March 13, 1950, datelined Washington under the title "Soviet Move Seen for Deal with U.S. to Divide World," of all the statements thus far published, seems to come closest to reflecting the official attitude of the United States. Its opinions are attributed to "United States officials," "the best-informed officials," and "experts in official quarters," and it appears under the byline of Mr. James Reston, the most brilliant, competent, and trustworthy of diplomatic correspondents.

Mr. Reston reports that "there is no evidence that officials here are even slightly interested in such a deal." Four reasons are adduced for this lack of interest, and it must be said from the outset that the first of these reasons is irrelevant to the argument and that the other three are entirely unconvincing.

A spheres of influence agreement, so that argument runs, "would force both Yugoslavia and China into a satellite status, and in the long run greatly strengthen the communist world." Whether all this would come to pass obviously depends upon the terms of the agreement. If such an agreement would extend the Russian sphere of influence beyond what it is now and strengthen the communist world while weakening the West, it should certainly not be concluded. However, this argument is valid only against the specific stipulations of a particular proposed agreement, which does not exist, but not against the very idea of negotiating some kind of such agreement. To say that such an agreement would necessarily be only to the advantage of the Soviet Union is really tantamount to taking a desperate view of both American power and American ability to negotiate. To use one of several possible lines of demarcation between the Russian and American spheres of influence as an argument against the very idea of spheres of influence is neither logical nor practical. It might well be that the Russian minimum conditions will be unacceptable to the United States, and it will then be necessary to reject them when they are proposed. But if the fear of such conditions were a valid argument against being even interested in negotiations, then few great nations would ever have engaged in negotiations in order to settle their differences by peaceful means.

The second reason concerning our influence among the Russian satellites, and the third one dealing with the problem of Stalin's succession, are contained in the following passages from Mr. Reston's dispatch: "The best-informed officials here do not think that the Soviet Union will be able to 'integrate' China and the European satellites unless we abandon those countries and force them to surrender to Moscow. They do not believe the problem of transferring power in Soviet Russia will be easy after Premier Stalin's death, especially if Yugoslavia and China are following an independent communist policy.

"In fact, the speculation here is that the primary objective of Stalin's policy now is to eliminate Premier Tito and Titoism and to consolidate the Soviet postwar sphere of influence before the problem of succession arises. Nobody here seems very eager to help the Russians solve this problem at the expense of other nations' freedom." The United States must refuse "washing its hands of Eastern Europe and China and forcing these peoples to make the best deal they can with Premier Stalin."

The second argument against spheres of influence is obscure, and the issue is confused, by the lumping together of China and Yugoslavia, on the one hand, and the satellite countries, such as Poland, Czechoslovakia, Hungary, Rumania, and Bulgaria, on the other. In the context of this discussion, the case of the former is quite different from that of the latter. Insofar as China and Yugoslavia are not, or not fully, integrated by the Soviet Union, a spheres of influence agreement will of necessity take this fact into account, and there can be no question of our washing our hands of them or bargaining their freedom away. As concerns the satellites themselves, they are already integrated; they have no freedom left for us to bargain away; and they slipped from our hands long ago. Their fate was sealed when we allowed the Red Army to occupy them and to keep them occupied. To liberate at least some of them means to force or to persuade the Red Army to retreat. To force the Red Army to retreat means a war which will destroy the satellite nations with the rest of us. To persuade the Red Army to retreat means —a negotiated settlement with the Soviet Union, which would receive a *quid pro quo* for that retreat. Thus "the best-informed officials" cannot well be concerned about the freedom of the peoples of Eastern Europe and at the same time oppose a negotiated settlement with the Soviet Union, for the one cannot be obtained without the other, at least not short of war.

The third argument, dealing with the import of Stalin's succession upon the situation of the satellites, is also somewhat obscure. Yet whatever it is intended to mean, it can be stated without equivocation that, short of the complete disintegration of Russian power, the problem of the succession can have no influence upon the Russian policy in the countries bordering the Soviet Union. For approximately two centuries, all Russian governments have considered the paramount influence of Russia in those regions as a *conditio sine qua non* of Russian security. This or another Russian government might well be induced to loosen its grip on Czechoslovakia or Hungary, which may well be regarded by the Soviet Union as liabilities rather than assets, and the Soviet Union might well accept a negotiated settlement which opens a graceful exit from those unruly and exposed regions. No Russian government will ever fail to subscribe to Stalin's statement at Yalta that Poland is "a question . . . of life and death for the Soviet State." Nations do not make questions of life and death an object of negotiation, and no Russian government will ever retreat from Poland unless compelled by defeat in war. If we wait for a change in the Russian government to bring about a change in the situation in the regions bordering on the Soviet Union, we might well wait forever.

The fourth argument against a spheres of influence agreement is generally couched in moral terms suggesting that the very idea of spheres of influence violates a fundamental principle of American policy. Here, this argument is given a legalistic turn,

derived as it is from the Charter of the United Nations. "This Charter, which was signed by the Russians and the United States, was based on the idea of all nations cooperating together in all parts of the world. It did not authorize the division of the world into two spheres of influence. . . ."

This is probably the most surprising of all the arguments advanced against the idea of spheres of influence and also the most deeply ingrained in the American political folklore. It found its most explicit expression in the comment which Mr. Cordell Hull made in his *Memoirs* on the Churchill-Stalin agreement with regard to the division of the Balkans. "I was, in fact, flatly opposed to any division of Europe or sections of Europe into spheres of influence. I had argued against this strongly at the Moscow Conference. It seemed to me that any creation of zones of influence would inevitably sow the seeds of future conflict. I felt that zones of influence could not but derogate from the over-all authority of the international security organization which I expected would come into being.

"I was not, and am not, a believer in the idea of balance of power or spheres of influence as a means of keeping the peace. During the First World War I had made an intensive study of the system of spheres of influence and balance of power, and I was grounded to the taproots in their iniquitous consequences. The conclusions I then formed in total opposition to this system stayed with me."

CHURCHILL AND TOYNBEE—TWO ADVOCATES OF SPHERES OF INFLUENCE

Mr. Churchill was tactless enough on that occasion to remind Mr. Hull of the peculiar position of the United States in the Western Hemisphere. And it is indeed obvious from the examples given above as well as from the political history of the human race that the balance of power and, concomitant with it, spheres of influence are of the very essence of international politics. As Arnold Toynbee puts it in a lecture given at Columbia University in 1948, applying his unequalled historic perspective to our problem: "I suppose that when two great powers face each other one possible alternative is a partition of the world without another war. If you look at the world now, as it has been since 1945, you can imagine it, if things should go rather well, being partitioned by agreement between the United States and the Soviet Union into two spheres.

"You may remember that before the First World War, France and Great Britain were great rivals about local frontiers in Africa, and so forth, and Russia and Great Britain were great rivals in Asia. In 1904 France and Great Britain went into consultation, worked over the map of the world, and wherever there was friction between them they ironed it out and made a bargain on a fifty-fifty basis: 'You have this, we keep that; and we will forget about that old quarrel of ours.' In 1907 Great Britain and Russia did the same. This is a difficult thing to do, in view of the traditional rivalries and dislikes of nations, and we succeeded in doing it in those cases only under strong pressure; we had a common aggressive enemy of whom we were all afraid, and that was Germany. But, after all, in the present situation America and Russia have a common enemy, too, of whom I am sure they are likewise afraid, and that is atomic energy. Though, no doubt, it needs great imagination to think of atomic energy as a common enemy whom you must not dare to let loose in the way in which Great Britain and Russia, and Great Britain and France, thought of Germany as the common enemy in the face of whom they must iron out their own former differences, perhaps it is conceivable that American and Russian statesmanship might rise to this and that there might be consultations in which they would say to each other, "You take Manchuria, and we will take the rest of China' and so forth around the globe. That would be hard on the countries that happen to be on the borderline, but it would really be much better for everybody if it could be achieved, rather than to have another war with its quite uncertain aftermath.

"I think this is an important possibility to keep in mind and to work for, because if it succeeded it might give us time, and, though sometimes playing for time merely means putting off something that we ought to settle now, I do not think that in our present circumstances playing for time is a wrong or unreasonable thing for us to try to do. . . . So anything that would enable us to buy time seems worth thinking about; and therefore I suggest a provisional partition of the world into a Russian and an American sphere by agreements between the two. If this could be brought about—if things are not too far gone for that—it would be a very valuable thing for both those great powers and for the world in general. It would give us time, among other things, to try gradually to build these two spheres together and eventually to unite them in a cooperative world government."

Mr. Churchill put it even more succinctly in his speech in the House of Commons on June 5, 1946: "It is better to have a world united than a world divided; but it is also better to have a world divided, than a world destroyed. Nor does it follow that even in a world divided there should not be equilibrium from which a further advance to unity might be attempted as the years pass by. Anything is better than this ceaseless degeneration of the heart of Europe. Europe will die of that." And we may add: and the Western world with it.

It is, then, our conclusion that we still do not know whether a settlement can be negotiated with the Russians. But neither do we know of an argument which would justify the refusal to try. For the real issue is not whether the very idea of the division of the world into spheres of influence can be accepted by the United States but where the line of demarcation should run. This is a matter for the dispassionate, realistic examination of the national interests of the United States and of the Soviet Union, the mutual relations of these interests, their conflicts and their identities, and the available power to support them. In the meantime, having to choose between Mr. Hull and his disciples who becloud the stark and simple realities of power politics with their "pernicious abstractions," on the one hand, and Mr. Churchill, on the other, we must be forgiven if we choose the latter. For on this momentous issue the voice of Mr. Churchill is not only the voice of the experience and the wisdom of the ages, but of plain common sense as well.

OCCURRENCE OF URANIUM DEPOSITS

W. H. Bradley

Much of the work done since 1941 on resources of radioactive raw material in the United States has been "classified" until recently. In the following article the Chief Geologist of the U.S. Geological Survey discusses uranium resources, classifying these by geologic types and noting their principal occurrence in various countries of the world.

ALL over the world a search for uranium prevails.[1] Until recently, except for those interested primarily in radium and vanadium, this research has been carried out exclusively by governments which attempted to keep secret their efforts and findings. This situation in considerable measure continues. Nevertheless, secrecy on these matters has lessened generally as evidenced by official statements made in such widely separated countries as Canada, Australia, France, Sweden, Norway, and South Africa relative to their radioactive resources and plans for utilizing them.

According to a recent report of the Joint Committee on Atomic Energy (Majority *Report* on the AEC investigation, p 11):

"To date, by far the larger share of uranium used by the U.S. issues from the Belgian Congo and Canada, with supplementary quantities derived from Colorado. Exploration on a scale recalling the 'gold rushes' of the last century has pushed forward throughout the globe; *but notwithstanding numerous "strikes" of lean ore and scattered lodes, there have been no reported new discoveries of extensive veins.*"

In this country the Government's geologic effort is extensive, with most of the exploration activities carried out by the U. S. Geological Survey; these activities include:

1. A comprehensive geologic study and exploration of the vanadium-uranium ores of the Colorado Plateau.
2. A comprehensive geologic study of the uranium-bearing phosphate and shale formations of the country.
3. A systematic examination of all mine dumps, mill tailings, smelter slag, and similar products for radioactive minerals.
4. A systematic study and extensive logging of oil and gas well holes for evidence of radioactive material.
5. Reconnaissance studies of so-called geologically favorable areas for evidence of unusually radioactive materials.
6. Spot examinations of all reported uranium prospects believed to have some chance of being important.
7. Geologic reconnaissance of river placer and beach sand deposits.
8. Examination of pegmatites as possible sources of uranium.
9. Laboratory studies involving the mineralogy and chemistry of uranium and research on the improvement and development of radiometric instruments and techniques.

Exploration for uranium deposits has resulted in their classification into three general types, namely, vein deposits, deposits in sedimentary rocks, and pegmatite deposits.

VEIN DEPOSITS

Veins containing cobalt and nickel minerals, in addition to other minerals of base metals and precious metals, such as those at Great Bear Lake and Lake Athabaska in Canada, in the Katanga province of the Belgian Congo, in the Erzgebirge region of Saxony and Bohemia, and in Cornwall, England, have been, to date, the major contributors to the world's supply of uranium.[2]

According to production figures published prior to World War II, the three most important uranium deposits in the world, all pitchblende vein-type deposits, are those at Joachimsthal in Bohemia, Eldorado in Canada, and Shinkolobwe in the Belgian Congo. Summary descriptions of these deposits follow.

Joachimsthal deposit.—The economic minerals in all the mines of the Joachimsthal district consist dominantly of minerals of silver, cobalt and nickel, bismuth, and pitchblende, in a gangue consisting largely of quartz, calcite, and dolomite. The veins range in width from a barely traceable film to some 40 inches—6 to 24 inches being the usual range of the worked veins. The veins follow long fractures and have been traced for thousands of feet along the surface. Pitchblende occupies various positions between the walls of the veins, rarely to the total exclusion of other vein-filling materials. It commonly occurs, with or without associated metallic minerals, as thin, fairly continuous seams, along both sides, either side, or in the middle of a vein of dolomite and quartz.

Silver ore is particularly abundant in the upper workings. Cobalt, nickel, and bismuth minerals are dominant in the middle levels of the mines, and pitchblende minerals are most abundant in the lower workings.

Eldorado mine.—The Eldorado mine is situated at LaBine Point, on Great Bear Lake, in Canada. The original mineral discovery on the southeast arm of McTavish Bay was made in 1900 when a field party of the Geological Survey of Canada noted that the greenstone cliffs on the east side of the Bay were stained with cobalt and copper. During 1930, Mr. Gilbert LaBine discovered silver and cobalt on a small island a short distance offshore from what is now known as the Eldorado mine.

The radium rush to the Northwest Territories that followed Mr. LaBine's discovery resulted in the finding of many additional veins—in the vicinity of the Eldorado mine, to the south at Contact Lake, Beaver Lodge Lake, Hottah Lake, and as far south as Lake Athabaska. Of these many discoveries only the veins at Eldorado have, to date, been important producers of uranium.

[1]References are at the end of the paper.

Pitchblende, silver, copper, cobalt, and nickel minerals are found at or near the surface in the productive veins at Eldorado. The outcrops are conspicuous by the presence of light-green, orange, and yellow secondary uranium minerals, pink cobalt, and green copper minerals. Mineralogy of the deposits is complex; more than 40 different metallic minerals have been identified, including pitchblende, chalcopyrite, cobalt-nickel minerals, bismuth, native silver, argentite, galena, and pyrite. Native silver is particularly abundant in the upper workings, but does not extend for more than a few hundred feet below the surface. The cobalt-nickel minerals are found in nearly all ore shoots and are more extensive than other types of mineralization. Pitchblende may form solid bands as much as a foot in width but commonly occurs as lenses only a few inches wide.

Shinkolobwe mine. — Although the presence of copper minerals in the outcrops of the Shinkolobwe ore body in the Belgian Congo had been known by the natives for many years, the existence of uranium was first discovered in 1915 by Major Sharp, who was exploring for copper 10 miles west of Jadotville. At the most westerly of these outcrops, which were distinguished by the presence of bright-yellow and green minerals, a ridge rose some 35 feet about the surrounding country. Here, in a shallow trench just below the soil cover, a large mass of what proved to be pitchblende was discovered. Trenching later revealed the existence of yellow, orange, and green uranium minerals accompanied by pitchblende. Mine developments, which were underway by 1921, soon proved ore bodies which were large and rich enough to enable the owner, Union Miniere, to capture the world's radium market from the poorer grade deposits of the Colorado Plateau and Joachimsthal. This virtual monopoly in the radium market continued until the development of the Eldorado mine in the 1930's.

In addition to the principal pitchblende-cobalt minerals at the Shinkolobwe mine, the ores carry significant quantities of copper, molybdenum and iron sulfides, thorium and tungsten, and gold, platinum, palladium. The oxidation of the ore bodies has extended several hundred feet in depth. In the near-surface deposits there are a host of complex hydrous oxides, phosphates, and silicates such as becquerelite, curite, uranophane, and torbernite. The torbernite accounts for more than half of the uranium in the oxidized zones of the ore body.

Other vein deposits.—Many vein deposits similar to that at Joachimsthal in Bohemia are known in Germany,[3] particularly at Johanngeorgenstadt, Schneeberg, Annaberg, and elsewhere in Saxony, and at Krzyzatka (Schmiedeberg) in Silesia. Russian examples are known in the Kara Mazar mountains of the Uzbekistan-Tadzhikistan frontier; British mines have been worked at South Terras and Wheal Trenwith in Cornwall; and American occurrences are recorded from Gilpin and Boulder counties, Colorado. Many small uranium deposits are also found in Portugal, where they are commonly associated with galena, chalcopyrite and pyrite, and with little or no cobalt, nickel, bismuth, or silver.

DEPOSITS IN SEDIMENTARY ROCKS

Uranium deposits in sedimentary rocks consist chiefly of carnotite deposits in sandstone and uranium-bearing marine rocks such as blackshale and phosphorite. Summary descriptions of these deposits follow.

Carnotite deposits.—The most extensive deposits of carnotite in sandstone are in this country, in an area known as the Colorado Plateau situated in western Colorado, eastern Utah, and northern Arizona.[4]

The carnotite deposits were discovered in 1899,[5] but only a small amount of ore was produced during the next decade. From 1910 to 1923 many of the deposits were worked for the radium they contained, and some vanadium and uranium were recovered as by-products. Though some of the deposits were mined from 1924 to 1936 mainly for vanadium, most of them were idle, but from 1937 through the war years the deposits were intensively worked again mainly for vanadium. During this last period of operation most of the ore averaged slightly less than 2 per cent V_2O_5 and about 0.25 per cent U_3O_8.[6] Many of the carnotite deposits are now being worked for uranium and vanadium.

The ore mainly impregnates sandstone, but some of the fossil plant material in the ore-bearing beds is richly mineralized. Ore bodies range from small irregularly shaped masses only a few feet across, containing only a few tons of ore, to large tabular bodies as much as several hundred feet across, containing many thousand tons of ore; most bodies contain less than a thousand tons each.

Other carnotite deposits.—Carnotite-bearing sandstones and conglomerates[3] are also known at various localities in Uzbekistan and Kazakhstan, U.S.S.R. Here, as in the American deposits, the yellow carnotite minerals are most often found in desert sandstones and conglomerates, and are richest around fossil vegetation and wherever bituminous matter is present. In one or two deposits the uranium minerals are in limestones which have been impregnated, particularly along joint- and bedding-planes, by the yellow lime-uranium vanadate tyuyamunite.

A type of deposit somewhat akin to the carnotites is found at Tyuya Muyun in the Fergana basin of Uzbekistan, U.S.S.R., this being the type locality for the mineral tyuyamunite.

Uranium-bearing marine rocks.[7]—Recent news items[8] to the effect that Sweden and possibly Russia are recovering uranium from marine oil shales indicate that some marine sedimentary rocks are important sources of uranium. Uraniferous deposits similar to those of Sweden and Russia are found in the United States, and published reports indicate, moreover, that such deposits are to be found in many countries, both large and small, over the world.

These deposits are large but low grade. Shales of the type Sweden and Russia are developing generally contain only 0.01 to 0.02 per cent uranium (one pound of uranium in 2.5 to 5 tons of rock), though some portions of the shales in Sweden contain as much as 0.5 per cent.[9] The small demand for uranium in pre-war years, when uranium was used principally as a coloring agent and as a source of radium, was met by mining small tonnages of much higher grade ore, containing 2 to 50 per cent uranium. Although some of the low-grade sedimentary deposits were known for many years, they were never seriously considered as a source of uranium. In the future, however, these low-grade sediments may well be the principal source of uranium and a source within the reach of many nations not previously believed to possess important uranium reserves.

The uranium content of the earth's crust has been estimated at 0.0002, 0.0004, and 0.0009 per cent by Anderson, Goldschmidt, and Fersman,[10] respectively. It is not surprising that certain rocks of marine origin contain 0.01 to 0.02 per cent uranium, for such a concentration is only 11 to 100 times that found in the earth's crust. Sedimentary iron, phosphate, and manganese-bearing formations commonly contain concentrations of iron, phosphorous, and manganese of 9, 100, and 500 times, respectively, the amounts found in the earth's crust.

Such concentrations are found in several classes of marine sediments, including beach placers and conglomer-

ates, but most of the known uranium-bearing marine rocks are of two principal types: black shale and phosphorite.

Uranium-bearing black shale.—Uranium in black shale was first discovered in Sweden in 1893 in alum shale.[11, 12] Since then uranium has been found in black shales of several other formations, including shales in Estonia and Russia,[13] which are similar to the alum shale in Sweden; the Chattanooga shale of east-central United States;[14] the Woodford chert of Oklahoma; the Nonesuch shale of Michigan;[15] and the Calico Bluff formation of east-central Alaska.

All marine bituminous or carbonaceous rocks are not appreciably uraniferous. The black shales of Maine and the asphaltic sands of California, for example, are not abnormally radioactive. The nonmarine oil shales, coals, and associated black shales, and asphaltites as a group, have an abnormally low uranium content; in fact, they are among the least radioactive of all rocks.[16]

All the highly uraniferous marine shales contain large amounts of organic matter, and it appears that, within a given formation at least, the most uranium is found in those rocks containing the most organic matter. For example, many layers of both the alum shale of Sweden and the Chattanooga shale contain uranium, but the highest concentrations in the alum shale are found in nodules and lenses of nearly pure bitumen, called "kolm"; and in the Chattanooga shale the most highly uraniferous beds are extremely thin layers of almost pure bitumen. In the Sunbury and Antrim shales, which are similar to the Chattanooga shale, the uranium content increases directly with increasing percentage of carbon.[17] The uranium-organic matter ratio differs in each of the uranium-bearing formations known, however, and, indeed may be found to differ from place to place in the same formation.

Uranium-bearing phosphorites.—Uranium in phosphorite was first discovered in 1924 in the phosphorite in Algeria.[18] Significant concentrations of uranium or radioactive substances have since been reported in other phosphorites in Egypt, Tunisia, and Morocco; in the phosphorites of the Ivota River region and the phosphorites of the Volsk region of Russia;[19] the Phosphoria formation of northwestern United States; and the Bone Valley formation of Florida. Uranium is found, too, in phosphatic nodules in many black shales, such as those at the top of the Checkerboard limestone member of the Coffeyville formation and of the Fort Scott limestone of Oklahoma;[20] the top of the R. C. Moore's Bourbon formation and in the Hushpuckney and Stark shales of Kansas. The small number of determinations available on other types of deposits, such as the residual deposits of Tennessee and Florida (the "hardrock" phosphate) and the guano deposits of the Pacific Islands, suggest that they do not contain significant amounts of uranium.

All marine phosphate formations thus far tested contain significant amounts of uranium. In a general way, the uranium content of the phosphorites increases as the phosphate content increases. A high-grade phosphate rock in one formation is likely to contain about as much uranium as does the same quality phosphate in another formation. Exceptions to this generalization are numerous, however, at least in the phosphorites of this country. Certain high-grade phosphate beds in the Phosphoria formation, for example, contain only small amounts of uranium, and the most uraniferous beds yet discovered in both the Phosphoria and Bone Valley formations are not the most phosphatic.

Miscellaneous uraniferous marine sediments. — Significant concentrations of uranium in marine sediments other than black shales and phosphorites are thus far known only in the gold-bearing conglomerates of the Witwatersrand,[21] South Africa, and beach placer deposits.

The origin of the South Africa Rand conglomerate is an enigma. No agreement has been reached as to whether the conglomerate is marine or nonmarine or whether the gold is placer or hydrothermal.[22] The mineralized layers are thin, but are remarkably continuous over great distances along the strike as well as down the dip of the beds. The extreme regularity and continuity

Courtesy—JUSTUS, *Minneapolis Star*

"Why All The Excitement, Brother?"

of the mineralized beds has suggested that the formation and its metals are of marine origin, but conclusive evidence is admittedly lacking. At least some, if not all, the uranium occurs as uraninite.[23]

Most radioactive beach placers are high in thorium rather than uranium, but the beach placers at Nome, Alaska, are uraniferous as well. Both zircon and monazite, which are found in many some, if not all, of the uranium occurs as uraninite.[23]

PEGMATITE DEPOSITS

Pegmatites are extremely coarse grained, light-colored rocks, commonly occurring in large veinlike formations which are associated with granite or other granitic rocks. The primary constituents of pegmatites are similar to those of granite, except that they usually occur in much larger crystals.

Uranium minerals are common minor constituents of pegmatite deposits, both in the United States and other parts of the world,[24] and they usually are closely associated with rare-earth minerals. As many as 71 uranium minerals and 72 rare-earth minerals, some of which may contain small amounts of uranium, have been noted.[25] Most of these 143 minerals have been recognized in pegmatites from various parts of the world, but they rarely occur in sufficient quantities to be economically important as a source of uranium.

The pegmatites in Madagascar are the only ones that have furnished appreciable tonnages of uranium minerals. Records indicate[26] the sale of over 100 tons of euxenite and betafite ores from Madagascar, together with about 37 tons of autunite and uranocircite ores recovered from peat beds, but probably derived indirectly from pegmatites. The production from other parts of the world has been limited, for the most part, to a few tens of pounds or a few tons of uranium-bearing minerals that were produced as by-products during mining for mica and feldspar.

The study of uranium minerals in domestic pegmatites has been carried on by the U. S. Geological Survey as part of its comprehensive investigation of pegmatites. During and after World War II more than 70 man-years of work were spent on the investigation of sheet mica, beryl, lithium, columbium, and tantalum deposits in all of the major pegmatite districts of this country. Many occurrences of uranium and rare-earth minerals were examined briefly. None of the known domestic deposits contains a sufficient quantity of uranium minerals to warrant mining for uranium alone, but it is possible that small quantities may be recovered from time to time as by-products of mining for other pegmatite minerals. Until large tonnages of pegmatite are mined and milled, the yearly production will continue to be, at the most, only a few hundred pounds or a few tons per year, and even if milling of pegmatite ores were to become a common practice, the production of uranium from pegmatites will probably remain comparatively small.

REFERENCES

1. Gustafson, J. K., "Impact of Atomic Energy on Economic Geology." Paper presented before Am. Inst. Min. Met. Eng., San Francisco, Calif., Feb., 1949.

2. Merritt, Phillip L., "Pitchblende—the Primary Source of Uranium." Paper presented before Am. Inst. Min. Met. Eng., San Francisco, Calif., Feb., 1949.

3. *A Prospector's Handbook to Radioactive Mineral Deposits.* London: Geol. Survey and Museum, 1949.

4. Fischer, R. P., "Vanadium Deposits of Colorado and Utah." U. S. Geol. Survey *Bull.*, Vol. 936 (1942), pp. 363-94.

5. ———. "Uranium-bearing Sandstone Deposits of the Colorado Plateau." Paper presented before Am. Inst. Min. Met. Eng., San Francisco, Calif., Feb., 1949.

6. Huleatt, W. P., Hazen, Scott W. Jr., and Traver, William M. Jr., "Exploration of Vanadium Region of Western Colorado and Eastern Utah," U.S. Bur. of Mines *Rept.*, Inv. 3930 (1946), p. 8.

7. McKelvey, V. E., and Nelson, John M., "Characteristics of Marine Uranium-bearing Sedimentary Rocks." Paper presented before Am. Inst. Min. Met. Eng., San Francisco, Calif., Feb., 1949.

8. "Uranium Ore Reported Discovered in Sweden," *Times Herald*, Washington, D.C., November 17, 1948.
"Uranium from Estonian Oil Shales," *Cincinnati Enquirer*, July 20, 1948.

9. Nordenskiold, A.E., "Remarques sur le fer natif d'dvifak et sur le bitume des roches cristallines de Suede," *Comptes Rendus*, Vol. 116 (Paris, 1893), pp. 677-78.
Landin, John, "Radium i Sverge," *Arkiv fur Kemi, Mineralogi, och geologi*, II (Jan., 1905), 1-7.
Eklund, Josef, "Atomic Energy and Economic Progress," *Skandinavisk Bauken Artiebalog Quarterly Review*, XXVIII (1947), 5-9.
Orlov, N. A., and Kurbatov, L. M., "The Radioactivity of Bituminous Shale," *Khimiya Tverdogo Topliva*, V (1934), 525-27; VI (1935), 288-91; VII (1936), 94-98.

10. Anderson, J. S., "Chemistry of the Earth," *Jour. Proc. Roy. Soc.* (New South Wales), LXXVI (1942), 329-45.
Goldschmidt, V. M., "Geochemische Verteilungs-gesetze der Elemente (IX), Die Mengenverhaltnisse der Elemente und der Atom-arten," *Skrifter det Norsk Videnskaps-Akademi*, I, "Mat. Nat. Klasse," No. 4 (Oslo, 1938), 58-62.
Fersman, A. E., *Geokhimia*. Leningrad, 1932.

11. Most of the publications listed below contain radium or uranium analyses. Assuming radium and uranium are in equilibrium, radium, which is generally reported in units of 10^{-12} grams of radium per gram of rock, can be converted to per cent uranium by multiplying by a factor of approximately 3×10^{6}. Most of the published determinations are not reliable because of the inaccuracy of early analytical methods.

12. Nordenskiold, A. E., *op. cit.*
Winkler, Clemens, "Zur Zusammensetzung des Eisens von Ovifak in Gronland und der bituminosen Kohle (des Kolms) aus der cambrischen Formation Westergotlands," *Zeitschrift für Krystallographie und Mineralogie*, XXXVII (Leipzig, 1903), 286-88.
Landin, John, *op. cit.*
Holmberg, B., and Unnerstad, A. J., "Destillationsforsok med bituminosa avlagringar from Billingen," Forsok med Billingens Kolm," Ingeniors Vetenskaps Akademien, *Handlingar*, No. 16 (Stockholm, Sept., 1922), pp. 71-78.
Wells, R. C., Stevens, R. E., "Further Studies of Kolm," *Washington Acad. Sci. Jour.*, XXI (1931), 409-14.
Eklund, Josef, *op. cit.*
Cadman, W. H., "The Oil Shale Deposits of the World and Recent Developments in their Exploitation and Utilization, Reviewed to May, 1947," *Inst. of Petroleum Jour.*, XXXIV (London, 1948), 109-32.

13. Orlov, N. A., and Kurbatov, L. M., *op. cit.*

14. Russell, W. L., "The Total Gamma Ray Activity of Sedimentary Rocks as Indicated by Geiger Counter Determinations," *Geophysics*, IX (1944), 197, 209.
Beers, R. F., and Goodman, Clark, "Distribution of Radioactivity in Ancient Sediments," Geol. Soc. America *Bull.*, LV (1944), 1243.

15. Holmes, Arthur, "Physics of the Earth: Part IV, The Age of the Earth," Nat. Research Council *Bull.*, LXXX (1931), 267.

16. Russell, W. L., Relation of Radioactivity, Organic Content, and Sedimentation," Am. Assoc. Petroleum Geologists *Bull.*, XXIX (1945), 1480.

17. Beers, R. F., "Radioactivity and Organic Content of Some Paleozoic Shales," Am. Assoc. Petroleum Geologists *Bull.*, XXIX (1945), 11.

18. Hebert, Claude, "Contribution à l'étude de la chimie des phosphates de calcium," *Annales des Mines, Memoirs*, Vol. 136 (Paris, 1947), pp. 5-93.

19. Rusakov, V. P., "O Soderzhanii Radiya i Toriya v Fosforitakh," Akademiya Nauk U.S.S.R., *Doklady*, Series A, No. 3 (Leningrad-Moscow, 1933), pp. 25-33.

20. Russell, W. L., *op. cit.*, pp. 205, 208.

21. Archambault, G. H., "South Africa Announces Rich Uranium Find," *New York Times*, Jan. 17, 1947.

22. Lindgren, W., *Mineral Deposits* (New York: McGraw-Hill, 1933), 240-46.

23. Bateman, A. M., *Economic Mineral Deposits* (New York: John Wiley, 1942), p. 443.

24. Page, Lincoln R., "Uranium in Pegmatites" Paper presented before Am. Inst. Met. Eng., San Francisco, Calif., Feb., 1949.

25. Ellsworth, H. V., *Rare Element Minerals of Canada* (Canadian Geol. Survey, "Econ. Geology Series," No. 11, 1932), pp. 45-53.

26. Hess, F. L., "Cobalt, Molybdenum, Nickel, Tantalum, Titanium, Tungsten, Radium, Uranium, and Vanadium in 1922, in 1923, in 1924," U.S. Geol. Survey, *Mineral Resources, 1922*, Pt. 1 (1924), pp. 557-83; *Mineral Resources, 1923*, Pt. 1 (1924), pp. 235-58; U.S. Bur. Mines, *Mineral Resources, U.S., 1924*, Pt. 1 (1926), pp. 451-76.

Correction

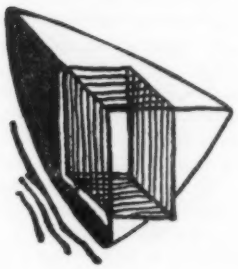
In last month's issue two lines were omitted from Dr. Szilard's footnote at the top of the third column on page 109. The middle paragraph should read:

"Fifty tons of neutrons should be produced if about 500 tons of heavy hydrogen is actually "burned." Since not all the neutrons emitted will necessarily be captured in the natural element which is incorporated in the bomb, and since not all the heavy hydrogen in the bomb need necessarily be "burned" in the explosion, the actual amount of heavy hydrogen that has to be accumulated might be considerably larger than 500 tons."

AEC SEVENTH SEMIANNUAL REPORT

A Condensation, Prepared by Anthony Turkevich

The Bulletin has regularly published condensations of the half-yearly reports which the Atomic Energy Commission submits to Congress. This most recent report, on the research activities of the Commission, has been condensed by Dr. Anthony Turkevich, Associate Professor at the Institute for Nuclear Studies at the University of Chicago.



THE Seventh Semiannual Report[1] of the Atomic Energy Commission, issued January 1950, is devoted mainly to the influence of Atomic Energy Commission activities on the physical sciences research of this country. This influence is exerted in several ways. First, there is an impressive quantity of research done in the Commission's laboratories. Then there is the support to university research through AEC or AEC-ONR research grants. Another influence is through the fellowship and training program of the AEC. Finally there are the special services such as radioisotopes, information services, irradiation of materials, and the like. The Seventh Semiannual Report details the accomplishments in all these directions.

RESEARCH IN AEC LABORATORIES

One of the important contributions of the AEC to research in the physical sciences in this country has been through the fundamental work carried out in its own laboratories.

The largest fraction of the research done at these laboratories is naturally directed toward the specific problems of the Commission. It is important because upon it depends the success or failure of the major immediate Commission enterprises, the production and improvement of nuclear weapons, the production of fissionable material, and the development of nuclear reactors for breeding and for power. Most of this research has to be kept secret. Much of it has little interest except to specialists.

At the same time the Commission has realized that its technical basis is in fields of science that are frontiers of knowledge; that its long-time accomplishments and the security of the nation demand that progress in nuclear physics and chemistry be furthered; that in many ways it is uniquely equipped to carry out fundamental studies in these fields; and that outstanding men can be attracted to its laboratories if these laboratories have the stimulus of fundamental research going on in their midst.

As a result of this philosophy of encouraging basic research in its laboratories — research that has general scientific interest and no immediate direct relation to the short-term problems of the Commission—the AEC has an impressive list of accomplishments to its credit. The following are some of the more important achievements:

Research in Nuclear Physics

It is understandable that the greatest results of the Commission in research should have been in the field of nuclear physics. One may argue that they would have been achieved someplace else if the Commission laboratories had not performed them, but at least the opportunities have not been neglected. The answers to some of the most fundamental physics problems are being sought in Commission laboratories.

Information about Light Nuclei.—The six simplest nuclei that can exist are the proton (H^1, nucleus of the hydrogen atom), the neutron (N^0), the deuteron (H^2, nucleus of the deuterium atom), the triton (H^3, nucleus of the triterium atom), the alpha particle (He^4, nucleus of the helium atom), and the Helium^3 nucleus (He^3). The relative stability of these nuclei, their characteristics, and the details of their interaction with each other form the most rigid quantitative test of any theory of nuclear forces. Four of these particles are well known; two (the triton and the He^3 nucleus) have been made in quantity for the first time by the Commission laboratories using the uranium piles. These laboratories have furnished much basic information about all these light nuclei.

"At Berkeley Radiation Laboratory, birthplace of the high-energy particle accelerator, two machines are in use to study one of the simplest of all interactions, that of protons with protons. The target bombarded is hydrogen, sometimes as a pure gas, sometimes in a solid substance such as paraffin. The projectiles are 32 million electron volt (Mev) protons from the linear accelerator and 350 Mev protons from the 184-inch synchro-cyclotron, most powerful accelerator known today." (p. 58)

"Hydrogen 3 or 'tritium,' the artificial radioactive isotope of hydrogen (half-life about 12 years[2]), has an unstable nucleus which contains a proton and two neutrons. By the emission of a beta particle tritium decays into helium 3, an isotope of helium with two protons and one neutron, which occurs in natural helium in the proportion of about one part in a million. When H^3 transforms itself into He^3, the changes that occur in such characteristics as the magnetism and spin of the three nucleons can be measured. In addition, there is a special interest in He^3 because it is the only known stable atomic nucleus that contains more protons than neutrons. For these reasons, and because of the relative simplicity of the

[1] Washington, D. C.: United States Government Printing Office, 1950.

[2] "The *half-life* is a convenient measure of the instability of radioactive nuclei, i.e., nuclei that are unstable and "decay" into other usually more stable isotopes, at the same time emitting particles and energy. It is the period of time in which one-half of the nuclei decay. In the next similar period, one-half of the remainder will decay, leaving one-fourth, and so on." (p. 59)

nuclei, physicists and chemists have sought to produce H^3 and He^3 for use in research. Argonne Laboratory announced in September 1948 that it can supply some quantities of both isotopes to scientists outside the atomic energy project, and both are now in use in studies of nuclear structure." (p. 59)

In one series of experiments, the Commission reports: "Deuterons are bombarded with tritons, and tritons with deuterons, to study reactions in which these two particles first combine then split into an alpha particle and a neutron. As the energies of the bombarding particles from a Cockcroft-Walton accelerator increase toward 100 thousand electron volts (100 Kev) the probability of the reactions occurring also increases (the triton's cross-section for deuteron capture is higher). But when energies of the incident particles are raised still higher by using a Van de Graaff generator, the capture cross-section falls off sharply.

"In a series of experiments with a Van de Graaff generator, tritium was bombarded with high-energy protons. The scattering of protons by tritons at various angles and energies was measured to derive data fundamental to the understanding of nuclear forces. At higher particle energies, the reactions in which the proton is captured by the triton were studied. In one of these reactions the resulting combination became an 'excited' alpha particle which converted itself to the stable state by emitting radiant energy in the form of 20-Mev gamma rays." (p. 60)

"In a second reaction observed, the proton-and-triton combination split into a neutron and a nucleus of helium 3. This latter reaction was of interest because it proved reversible; that is, helium 3 bombarded with neutrons yielded protons and tritons.

" 'It was possible here,' the report of the experiment states, 'since good measurements existed on this reaction going in either direction, to verify a well-known theorem of statistical mechanics which relates the reaction probabilities of such a reversible system; this was the first time that an experimentally adequate check of the "principle of detailed balance" had been made for a nuclear reaction.'

"These reactions permitted more accurate determination than ever before of the size of the mass difference between the neutron and the proton, and consequently of the mass of the neutron itself. Results obtained in other laboratories confirmed these findings and did away with previous discrepancies." (p. 59-60)

High Energy Accelerators.—As is well known, the forces at the nucleus and holding it together are so strong that high energies are needed to induce most nuclear reactions. Moreover, one of the keys to understanding nuclear forces is now thought to be in understanding unstable particles called "mesons." These particles had been predicted and their importance emphasized in 1935 by the Japanese theoretical physicist Yukawa. Mesons can be produced only by use of very high energies. In fact the energy needed to produce mesons is about ten times that needed to induce most simple nuclear reactions.

Until recently such energies were available only in the "cosmic radiation." By studying "cosmic radiation" at high altitudes, English researchers discovered two kinds of mesons in 1947. The Commission and the ONR have collaborated in sponsoring such cosmic ray research in universities. Meanwhile, the desire for laboratory production of high energies has impelled the Commission to support the development and use of high energy accelerators. The Report gives details on the status of this program.

Besides the more conventional accelerators in their laboratories (cyclotrons, Van de Graaff generators, etc.), the Commission has had available recently a 32 Mev proton linear accelerator and a 184-inch synchrocyclotron, capable of producing 350 Mev protons. Both machines are at the Radiation Laboratory at Berkeley. The synchrocyclotron is the most powerful accelerator existing today. For the future, the Commission is supporting the construction of two machines (one at Berkeley, the "Bevatron"; one at Brookhaven, the "Cosmotron") capable of producing particles with billions of electron volts.

Results with High Energy Acceleration.—The outstanding achievement to date with the existing machines was the artificial production of the meson with the synchrocyclotron in 1948. These particles are now available in the laboratory in intensities many times higher than those existing in high altitudes in the cosmic rays. The properties of mesons are being studied. The mass of the "pi" meson has been determined to be between 270 and 282 times that of an electron. Experiments at Berkeley (artificial meson) and Brookhaven (cosmic ray mesons) have confirmed the instability of the "pi" meson. The average "pi" meson decays in about one hundred millionths of a second into a lighter 'mu" meson. This "mu" meson has a mass about two hundred times that of an electron and an average life of around two millionths of a second. It decays into an electron and two or more unknown neutral particles. The yield of mesons when different targets are bombarded has also been established.

All the mesons experimentally established to date (both "pi" and "mu") have been charged mesons (either positive or negative). It is of great theoretical importance to establish the existence and properties of neutral mesons. These particles are being looked for at the 180-inch synchrocyclotron at Berkeley, and an electromagnetic radiation has been observed which has some of the characteristics expected for the product of the decay of a neutral meson.

The 180-inch synchrocyclotron has also yielded results in the field of very high energy nuclear reactions. With the more conventional machines yielding rather low energies it had been found that the most common nuclear reactions involved the "chipping off" of a few light particles (neutrons, protons, or alpha particles). With a few special nuclei (those of the heaviest elements, thorium, uranium, plutonium), fission—that is, break-up into two more or less equal parts—could be induced with the low energies.

With very high energy bombarding particles it has been found possible to "evaporate" as many as twenty or more light particles from a nucleus. A target composed of one type of nucleus can yield as many as 100 different radioactive decomposition products. These nuclear reactions have come to be known as "spallation reactions."

The very high energies available at the synchrocyclotron have also been used to establish the fission of bismuth, lead, gold, and other heavy elements if the energy is high enough. Moreover, the characteristics of nuclear fission at these energies have been studied. It appears that the tendency is to split into two equal particles (low energy fission tends to form somewhat unequal fragments). Very often, at these energies, a nucleus will boil off some neutrons *before* it undergoes fission. The neutrons accompanying the more conventional type of fission of, say, uranium, are thought to come off during or after the fission act.

Both high energy fission and spallation reactions have derived application as a means of producing radioactive products. Many of these had never been made before and most cannot be made either in chain reacting piles or with more conventional accelerators.

Besides giving potentially useful products, these new nuclear reactions represent still another approach to the

unsolved problem of nuclear forces and so merit attention from the theoretical standpoint also.

Research with Neutrons.—The large-scale application of nuclear energy to date is intimately tied up with the special properties of the fundamental particle, the neutron, which was unknown twenty years ago. It is not surprising, therefore, that a good deal of the research effort in the Commission laboratories is engaged in the study of this particle. There is a continual study of new and better means of producing neutrons, either in higher intensities, or of more monochromatic energies. These sources are used then to study the modes and intensity of interaction of neutrons with all the isotopes of all the elements of the periodic table. This gives important information not only to technical people designing nuclear reactors, but also to nuclear theoreticians looking for quantitative data and regularities in nuclear structure. Research is also continuing on the predicted instability of the neutron and its structure. The neutron is energetically unstable with respect to decomposition into a hydrogen atom and is expected to have a half-life of less than thirty minutes. Usually it gets swallowed up by other nuclei long before this. Attempts are continuing to actually detect the decomposition and measure the half-life. Similarly, current theory predicts that a neutron should behave partially like a proton with a negative meson cloud around it. This would give rise to a feeble interaction between a neutron and charged particles. Attempts are continuing to detect and measure this interaction.

Research on the Nuclear Properties of Heavy Elements.—Uranium and thorium nuclei are the most important raw materials of the atomic energy program. The products of this program are special nuclei of the heavy elements. It is natural that the Commission should try to find out more about nuclear properties in this region of the periodic table.

All the elements of higher nuclear charge than bismuth and lead are radioactive. All except thorium and uranium are so unstable that only extremely minute quantities exist in nature. Ten years ago only forty two of the unstable nuclear species in this region had been characterized. Today more than triple this number are known. For example, there are eight isotopes of plutonium known today. Investigation of the decomposition mechanism of these isotopes has led to an estimation of energetic relations among nuclei in this region. It is possible now to predict much more reliably the properties of unknown nuclei that might be important for one reason or another.

Theoretical Research.—On the theoretical side Commission workers have been among the leaders in establishing the existence of the so-called "magic numbers" in nuclear structure. Nuclei containing 20, 52, 80, or 128 neutrons or protons appear to possess an extra stability compared to neighboring nuclei. The effect of these "magic numbers" is also reflected in the magnetic properties and mode of interaction with neutrons of these nuclei. These ideas are considered to be one of the most significant advances in thinking about nuclei since the war.

There has also been progress in the development of mathematical tools available to solve theoretical problems. "Mathematics is the language of nuclear theory, and all of the National Laboratories have organized working teams of mathematicians. These teams develop the formulas that describe nuclear phenomena and translate them into numerical quantities which they check with the results of experiment. Once experimentally verified, the formulas are then used to predict future results and guide further experimentation. The so-called Monte Carlo system used in atomic energy laboratories is typical of the new mathematical techniques.

"The Monte Carlo system is used, for example, to determine the effectiveness of the shielding structure planned for a particular reactor. To make the calculation, the mathematician traces the course of a single hypothetical neutron through the maze of atoms in the shield to its final destination. Sheer chance determines how often this neutron will collide with a shield atom and which way it will rebound. In the mathematical solution, therefore, the distance between collisions and the direction of travel after collision are determined by means of 'random numbers,' like the numbers that could be obtained from repeated spinning of a perfectly balanced roulette wheel (hence the system's name). As the result of these chance collisions, the neutron may bounce about within the shield until it is captured by an atomic nucleus, or it may escape quickly to the outside, or it may follow any of an infinite number of courses between these two extremes. By following the behavior of a great many such hypothetical individual neutrons, the mathematician can determine the statistical behavior of the group—that is, all of the neutrons that will strike the shield. Any desired accuracy can be achieved by increasing the number of individual calculations.

"Ever since the earliest days of the atomic energy project there has been a need to solve very complex computational problems, such as are involved in bomb design, pile construction, thermal diffusion, electromagnetic separation of isotopes, and problems in pure physics. Solving a single problem may involve some tens of thousands of individual operations, and in some instances the number is larger. To tackle such problems at Los Alamos, large groups of computers using desk machines were formed; in other cases, where simple and highly repetitive operations permitted, electromechanical computers were brought into use.

"One development carried on during the war at the Army's Aberdeen Proving Ground was the construction of an electronic digital computer, the so-called Eniac. Its success has provided considerable stimulation in this new field.

"The Commission is supporting in part the development and construction by the Institute for Advanced Study at Princeton of an electronic computer which will be ideally suited to handle many of the theoretical problems arising in nuclear research. This device will be completed during 1950. Construction of computers based on this prototype is already under way at Los Alamos and Argonne. Thus these AEC laboratories will have at their disposal the most modern means of scientific computation and will be able to handle problems not possible with existing computers.

"To further the development and utilization of mechanical computing devices, the Commission has assisted, through contract, in financing the 12-hour-a-day operation of Harvard University's Automatic Sequence Controlled Digital Calculator, more familiarly known as the Mark I Computer. The problems turned over to this computer are selected by a committee of Harvard scientists and have ranged in scope from the detailed investigation of the force constants necessary to bind the neutron and proton together to studies in heat radiation applicable to stellar (and also to atomic weapon) problems. Between these extremes of the small and the great, the machine has helped in solving engineering and medical research problems—having dealt, among other things, with the propagation of

flames, the principles of streamlining, the electromagnetic radiation from systems immersed in conducting media, and the dimensions of asymmetrical molecules." (pp. 85-87)

Research in Chemistry

The chemical research of the Commission laboratories involves research with practically all the elements of the periodic table. The main emphasis is, however, on the very light elements, hydrogen and helium; the very heavy elements, uranium, plutonium, etc.; and somewhat less emphasis on the middle weight region.

The great advances in research among the light elements, hydrogen and helium, arise from the Commission's production on a relatively large scale, of the nuclei of tritium (T or H^3) and helium —3 (He^3). Tritium is produced in the chain reacting piles by the irradiation of lithium with neutrons. Tritium is unstable, half of it decaying into He^3 in around twelve years. Since neither nuclei exist in nature in any appreciable amount, their production by the Commission represents the first amounts of any size available for research. Tritium is an isotope of hydrogen, just like deuterium.

The importance of tritium is two-fold. In the first place it is the only radioactive form of hydrogen and so is an important method of "tracing" hydrogen. Although its radiations are somewhat hard to measure it is certain to find wide use in both research and industry.

The second importance of tritium lies in the fact that only for the simplest chemical molecule—the hydrogen molecule—can accurate theoretical calculations and predictions of the chemical behavior be made. Since tritium and deuterium are isotopes of hydrogen, there now exist six different types of hydrogen molecules (H_2, D_2, T_2, DH, TH, TD) for which the comparison between theoretical prediction and experimental results can be made. One such set of experimental data are the spectra of these molecules—the light given off by these molecules after excitation, say in a discharge tube. Much of this spectral data has been determined in Commission laboratories in collaboration with Johns Hopkins University and is being analyzed theoretically.

The other significant advance in the chemistry of light elements made as a result of the production by the Commission of He^3 and H^3 has been in the field of low temperature research. "Helium 4 and helium 3 have been found to have very different properties at temperatures close to absolute zero.

"The rate of flow of liquid helium 4 through a small opening decreases as the temperature is lowered—until the temperature reaches within a few degrees of absolute zero. But below this temperature its behavior abruptly changes. Instead of becoming more sluggish, helium 4 enters the so-called fourth state of matter in which the element becomes a super heat conductor and a super fluid. It is able to leak through openings so small as to hinder the movement of gaseous particles, and actually creeps up and over the walls of its container.

"Helium 3, the rare isotope of helium, is chemically almost the same as He 4, but scientists wondered if the fact that it had only one neutron, instead of two, would make a difference in its behavior at low temperatures. Recent investigations have indicated that, even within one degree of absolute zero, He 3 displays no signs of superfluidity." (p. 108)

In the chemistry of the heavier elements, a good deal of effort is being placed on the study of the chemistry of thorium, uranium, plutonium, and other transuranics. The results are in many cases secret, since they bear strongly on the technical aspects of separating plutonium from the uranium in which it is formed in the chain reacting piles. In nonsecret research the Commission reports that "Los Alamos chemists have succeeded in separating a small quantity of Americum (atomic number 95; atomic weight 241)." Americum is one of the transuranic elements produced for the first time in the chain reacting piles. Its chemistry had hitherto been studied only through its radioactive properties since not enough material has been available to use more conventional methods.

In many ways the chemistry of the very heavy elements resembles that of a group of elements in the middle of the periodic table, the so-called "rare earth" elements. "Most chemists knew very little about these rare earths in 1940. They occur together in nature, and—because they were so hard to separate and had not been of any great practical importance in the past—their chemical properties were little understood. The developers of atomic energy had to get the facts about these rare earths; the work to be done fell within the field of fundamental, experimental, and theoretical chemistry.

"Ames and Oak Ridge laboratories have pioneered the basic studies of, and the development of separation methods for, the rare earths. Their most successful method has been a refinement of the ion-exchange process. In this process, a solution containing rare-earth elements is allowed to flow downward through a long thin vertical tube which is packed with resin. This solid resin removes the various elements from solution by the process of ion exchange. After the rare earths are absorbed on the resin, a weakly acid sodium citrate solution is poured through the column. Under the action of this solution, the grip of the resin upon the rare earths seems to be loosened, but to a slightly different degree for each rare earth element present. As the solution passes down the tube the rare earths begin to be carried with it, but at different rates, so that the solution as it emerges from the bottom of the column is found to carry one rare earth for a time, and then another for a time, then a third for a time, and so on. By collecting these fractions in different vesels, chemists achieve a separation of the component rare earth elements." (pp. 101-102)

One of the applications of the development of this method for the separation of rare earths has been to the products of uranium fission. As a result of this "Oak Ridge Laboratory has been internationally accredited with the discovery of element 61, promethium, isolated by the ion-exchange process from reactor products. This laboratory, also, is the first producer in any quantity of technecium (element 43)...." (p. 102) Both these elements are radioactive. Thus the last two gaps, in the main part of the periodic table of elements have been filled in through the application of chemistry to uranium fission products.

AEC SERVICES TO RESEARCH

Another impact of the Atomic Energy Commission on research in the physical sciences in this country has been through special services which it offers to research workers. The irradiation with neutrons of samples in the chain reacting piles is one such service.

The Commission has also encouraged the training of scientists in the new techniques developed as a result of the availability of radioactive and stable isotopes. The Oak Ridge Institute for Nuclear Studies has presented courses in these techniques. "Through a series of 11 courses, 318 scientists from over 170 laboratories in this country and abroad have been trained." (p. 151)

Another is the preparation and distribution of radioisotopes (prepared in the piles or cyclotrons) and separated

stable isotopes (concentrated in the electromagnetic separation plant at Oak Ridge). About eight hundred shipments a year are made to research workers in physics and chemistry. These are research aids that would probably not be available at all without the Commission's efforts.

AEC FELLOWSHIP PROGRAM

The Seventh Semiannual Report also states the present status of the Atomic Energy Commission fellowship program. This had been established in 1948 in order to aid research students at the predoctoral and postdoctoral levels. The National Research Council has been administering the program — selecting the fellows, approving the research projects and evaluating the fellows' progress. In the two full years of operation a sum of $1,200,000 has been granted to about 500 participants. Less than 10 per cent of the participants have been working on subjects or in areas that are classified as secret.

In the fall of 1949 Congress attached a rider to the Independent Offices Appropriation Act for 1950. "The rider provided that any person receiving an AEC fellowship award must undergo a loyalty clearance, whether or not his particular research project requires him to have access to secret information. Under previous provisions, security clearance was required for fellows only when their project involved restricted data." (p. 148)

As a consequence of this, predoctoral fellowships for the year 1950-51 (except for renewals) will not be offered at all through the NRC. The AEC is trying to set up a system of granting such fellowships through university groups in various sections of the country, but this will take time. In the postdoctoral field for 1950-51, the NRC will continue to select fellows but only for advanced training in fields of research closely related to the national atomic energy program.

"Complying with the Appropriation Act, signed by the President on August 24, 1949, the Commission established procedures for FBI investigations of all AEC fellows and for the screening, analyzing, and reviewing of the investigative reports.

"In cases where the fellow would not have access to restricted data, and no derogatory information is found, a fellowship-type approval is granted. Where the investigation has reflected some derogatory information about an applicant for a nonsecret piece of research, the reports are reviewed by a panel. The panel applies the same criteria used by the President's Loyalty Review Board established under Executive Order 9835. After reviewing the panel's recommendations, the General Manager decides whether fellowship approval should be granted.

"If the fellow is to have access to restricted data, the investigative reports are evaluated in accordance with the Commission's criteria for determining eligibility for clearance for AEC and contractor employees.

"Of the 421 who now hold AEC fellowships, 30 are engaged in research work which requires them to have access to secret atomic energy data (they already have received full AEC security clearance) and 391 are in nonsecret work. All save 77 of these fellows in nonsecret work were appointed before August 24 when the Appropriations Act went into effect, and hence they have been required only to sign a loyalty oath and noncommunist affidavit, as has been required of all fellows since May 22. The other fellows, appointed or reappointed after August 24, are of course subject to loyalty investigations as described above.

"Under the NRC program set up for the 1950-51 year, about 75 new fellowships and 175 renewals will be offered. The cost of this program will run between $600,000 and $900,000, depending on the number of new awards made. The AEC will continue fellowships in health physics—it will offer about 20—which formerly were a part of the Research Council's predoctoral program, and will work out an alternate system of administration. These fellowships always have required full security clearance and will continue to do so." (pp. 149-150)

INFORMATION SERVICES OF THE AEC

"As a producer of information, the Commission is required by the Atomic Energy Act of 1946 to maintain 'a program for the control of scientific and technical information which will permit the dissemination of such information to encourage scientific progress.'" (p. 162)

"The job of accomplishing this dual purpose (controlling and disseminating information) is complicated by decentralized research and reporting activities. In 1949, 350 contractors produced about 4,000 reports, of which 2,900 were classified and subject to security control and limited distribution." (p. 162)

The cataloging, abstracting, distribution, and control of classified reports is an internal problem for the AEC. The dissemination of unclassified information concerns the outside world. "As a major method of dissemination (of unclassified or declassified research), the Commission encourages project scientists to make their own arrangements for publication in established, privately-supported scientific periodicals.

"The Commission's policy in this regard is supported by an overwhelming number of project scientists who do not wish to see the Commission or any other part of the Federal establishment assume the responsibility for publishing their contributions to research. Unfortunately, private scientific societies are unable, at the present time, to publish all results of the greatly expanded volume of federally supported research.

"The National Research Council will shortly organize a conference of editors of the leading scientific journals to formulate their views on the extent of Federal responsibility for the support of scientific publication. The Atomic Energy Commission will weigh the result of this conference before attempting to estimate the extent of its obligation to extend financial support to such journals.

"In the meantime, the Commission is reproducing and distributing the unclassified and declassified AEC reports which have not been published in the regular scientific journals. These reports are available on an exchange basis to universities, learned societies, research institutions, etc., and are sold to individuals or institutions unable to enter into exchange arrangements.

"As a final method of disseminating unclassified scientific and technical information, the Commission has established the 'National Nuclear Energy Series.'" (pp. 165-166)

The National Nuclear Energy Series developed by condensation of separate writing programs originating at Chicago, Berkeley, Los Alamos, and other project laboratories. Each site planned to write scientific accounts of its research programs. By November 1945, arrangements were completed to combine all the separate programs into one over-all series covering all phases of the project. The classified volumes (approximately 60) will, of course, be available only within the atomic energy project. The remaining 50 volumes will be declassified and made available to the general scientific and technical community.

"As part of its general policy to encourage private publication of unclassified research results, the Commission invited bids from private firms for publishing the Series. The McGraw-

Hill Publishing Company was selected and has already issued eleven volumes, the first of which appeared in 1948." (pp. 166-167)

"Although the Commission is not a major publisher of unclassified scientific papers, it has established a major abstracting publication in the field of nuclear science. 'Nuclear Science Abstracts' in less than two years has become a valuable tool for research workers. The Commission publishes the abstracts to meet such problems as the fact that (a) existing abstract services like 'Chemical Abstracts' and 'Physics Abstracts' do not cover unpublished research reports; (b) program research requires faster abstracting services than existing abstracts provide; and (c) nuclear science cuts across many diverse fields such as medicine, agriculture, geology, ceramics, industrial sanitation, instrumentation, metallurgy, chemistry, and physics.

" 'Nuclear Science Abstracts' is issued twice monthly at Oak Ridge.

FINANCIAL ASPECTS OF AEC RESEARCH PROGRAM

"Estimated costs of Commission activities during the fiscal years 1949 and 1950 reported in the President's budget for the fiscal year 1951 are as follows: (p. 27)

(Millions of dollars)

	Fiscal year 1949	1950
Operations	$293	$358
Plant and Equipment	338	340
Totals	$631	$698

The AEC physical research operating costs, exclusive of depreciation, are expected to increase from approximately 26 million dollars in fiscal year 1949 to over 31 million dollars in fiscal year 1950.

"In all, about 8 million dollars is likely to be spent for physical research this year through off-site contracts, compared with about 23 million dollars in the 12 major atomic energy research laboratories. These sums pay only salaries and laboratory operating expenses, plus occasionally the cost of some minor equipment. Construction of facilities and major equipment is budgeted separately. Scientific and technical personnel engaged in the 31-million-dollar physical research program number about 2,150, almost a fourth of the technically trained people employed in all operating phases of the Commission's research and development program.

"In reactor development, the operating budget for this fiscal year calls for another 12 million dollars in off-site contracts. This is in addition to about 21 million dollars in Government-owned laboratories.

TABLE 1

MONEY AND MANPOWER FOR RESEARCH AND DEVELOPMENT, ESTIMATED, 1950 (p. 53)

(Approximate figures)

	Physical Sciences		Reactor Development		Biological and Medical Sciences		Total	
	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists
8 major Government-owned atomic energy laboratories	18	750	21	900	7	300	46	1,950
4 major university-owned atomic energy laboratories	5	600	—	—	3	350	8	950
Many off-site industrial, educational, research, and Government activities	8	800	12	1,000	7	700	27	2,500
Total	31	2,150	33	1,900	17	1,350	81	5,400

Table 1 shows expected dollar costs and scientific employment in the AEC programs in the physical sciences and reactor development in fiscal 1950, compared to the corresponding figures for the biological and medical sciences. The 27 million dollars for work outside the 12 major laboratories includes basic research funds in colleges and universities totalling 6.5 million dollars in the physical sciences and 4.3 million dollars in the biological and medical fields. Included also among the 2,500 scientists in this off-site group are over 500 graduate students working on the university contracts." (pp. 52-53)

"The 5,400 total of scientific and technical personnel among these laboratory and off-site groups is more than half of the total employed on the Commission program. Of the others, nearly 4,000 work on the development of new weapons and on research and development projects directly associated with the production of fissionable material. Another 500 are on the Commission's staff in Washington and in the several field offices." (p. 53)

"One of the more significant developments is the large increase of work performed outside the Commission's own laboratories and installations. In fiscal year 1949, such work made up 14.5 per cent of the total physical research program, and in fiscal year 1951 contracts for work outside Commission-owned laboratories are expected to reach nearly 32 per cent of the program. While the work in Commission-owned laboratories by major research contractors will remain fairly constant, work in the laboratories of educational and research institutions under the much more numerous smaller contracts will increase substantially. This indicates a real growth of scientific effort in this very important field." (p. 161)

"In addition to the 31 million dollars for operating physical research, 25 million dollars is being spent during this fiscal year on the construction of new physical research facilities and equipment. Among the major items are $250,000 for completion of a research building at Ames, $125,000 for the start of a new research reactor at Argonne, 4.5 million dollars for work on the bevatron at the Berkeley Radiation Laboratory, over 2 million dollars on the cosmotron at Brookhaven and about 5.4 million dollars for permanent buildings at the Oak Ridge National Laboratory.

"For the construction of reactors and associated plant and equipment costs, 41 million dollars will probably be spent this year. Of this, 8.5 million dollars is going into the new Reactor Test Station at Idaho, nearly 3 million dollars for the Intermediate Power Reactor at the Knolls Atomic Power Laboratory, and about 22 million dollars at Argonne. New laboratories at Bettis Field for the Westinghouse contract are costing over 3.5 million dollars." (p. 54)

"The Atomic Energy Commission's total operating and capital outlay in its three basic research and development programs during the year that ended June 30, 1949, was approximately 128 million dollars. This amount covers research in physical science, biology and medicine, and reactor development but does not cover research of the process-improvement type which is included under the weapons and source and fissionable materials programs. Of this amount approximately 53 million dollars was spent on research in the physical sciences. In comparison, according to a report of the President's Scientific

Research Board, all other civilian agencies of the Government were expending in 1947 a total of 20 million dollars for basic research and 105 million dollars for applied research and development projects." (p. 153)

AEC SUPPORT OF UNCLASSIFIED RESEARCH IN UNIVERSITY LABORATORIES

"The Atomic Energy Commission contracts for basic unclassified research in university and college laboratories currently at an annual rate, for research in the physical sciences, of about 6.5 million dollars. These contracts are for two sorts of research: *a*) Basic research to solve a particular problem such as one dealing with reactor design or isotope separation. The Commission seeks the services of specific scientists under these contracts and usually pays the full costs. *b*) Basic research of the typical university sort, undertaken to add to the general fund of knowledge applicable to atomic energy development. The Commission shares research costs of these projects to an extent arrived at by negotiation.

"Many of the university and college scientists now engaged on these contracts helped staff the wartime atomic energy project. They include some of the nation's leading workers in fields related to atomic energy. When AEC determined to support unclassified basic research, it sought the assistance of these men. The problem was how to enable them to undertake additional research, of interest to the progress of the atomic energy enterprise, without depriving their students of essential training.

"Inquiry revealed that many of the scientists could take on AEC projects if the handicap of lack of financing were removed. AEC funds in limited amounts would correct these deficiencies, and increase the volume of basic atomic energy research. From the university's viewpoint, and that of the national interest also, a method of control had to be established to assure that contract research work would not encroach seriously on the major university task of training more scientists. The procedure adopted stipulates that the AEC will receive proposals for basic research through the management of universities and colleges where capable scientists are willing to expand or to continue a research program, provided their projects are such that they might be of interest to the development or use of atomic energy. The fact that proposals funnel through the management of universities enables the institutions to assure themselves control over the volume of research.

"The present mechanism for receiving, reviewing, and deciding on basic research proposals in the field of physical sciences was set up after careful study and some experience in operation.

"A proposal from a university for the mutual support of a research project is studied by scientists who consider many factors before making a judgment as to whether the work should be supported by an appropriate amount of Commission funds. They consider: (*a*) scientific achievements already made by the university and scientist concerned, and the probability of continued research performance; (*b*) importance of the proposed project to atomic energy development; (*c*) general need of the AEC for more individuals trained in the field of study involved; (*d*) financial condition of the university involved and the relationship that additional funds might have to program expansion; (*e*) likelihood that information affecting the security of the Nation will be developed

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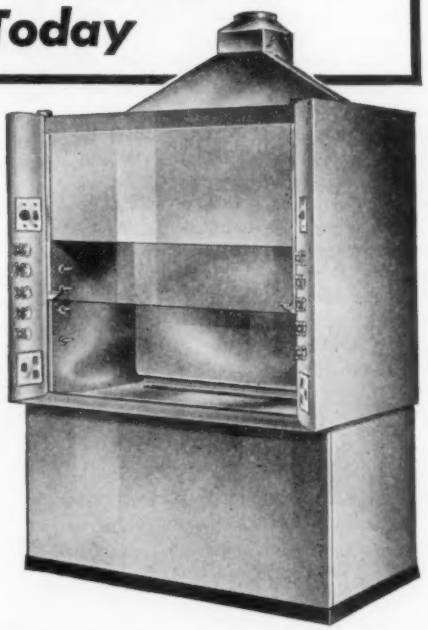

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and feasibility of providing the safeguards that might become necessary." (pp. 151-153)

RELATION OF AEC TO OFFICE OF NAVAL RESEARCH

"In 1947 when the Commission became responsible for advancing atomic energy research, virtually the only Government assistance being given universities in the vital field of nuclear research came from the Office of Naval Research. The funds available, even for this limited support, were diminishing. More than two years ago, therefore, AEC commenced contributing to the support of this work. Today there are 63 ONR-AEC research projects in physical sciences in American universities.

"ONR and the AEC are currently agreeing on which specific projects in nuclear physics should be supported in whole by ONR, in whole by AEC, and jointly by ONR and AEC. By the last quarter of calendar year 1949, AEC had contracted for research, or transferred to the Office of Naval Research for contracts, the following sums: in physics research, a total of 6.3 million dollars of which 5 million dollars was administered by ONR; in chemistry research, a total of $400,000; in metallurgy, all handled by AEC, some $1,100,000; in mathematics, about $200,000 of which AEC administered all except about $14,000. The total is about $7,900,000 of which AEC directly administered about $2,900,000 and ONR about $5,000,000." (p. 153)

BOOKS RECEIVED

Elementary Pile Theory. By HARRY SOODAK and EDWARD C. CAMPBELL. New York: John Wiley & Sons, Inc., 1950. Pp. 71. $2.50.

Geo-Economic Regionalism and World Federation. By MAURICE PARMELEE. New York: Exposition Press, 1949. Pp. 137. $2.50.

Heredity East and West. By JULIAN HUXLEY. New York: Henry Schuman, Inc., 1949. Pp. 246. $3.00.

Illusions of Point Four. By HENRY HAZLITT. New York: Foundation for Economic Education, 1950. Pp. 48. $0.50.

Man's Last Choice. By E. M. FRIEDWALD. New York: Viking Press, Inc., 1948. Pp. 128. $2.00.

Militarism in Education. Research and preparation by JOHN M. SWOMLEY, JR. Washington: National Council Against Conscription, 1950. Pp. 80. $0.25.

BOOKS

Atomic Medicine. Edited by C. F. BEHRENS. New York: Thomas Nelson & Sons, 1949. Pp. 416. $7.50.

CONTEMPORARY research in nuclear physics has an obvious effect on medical practice. On the one hand, the physician is confronted with a rapid extension of knowledge of the intimate behavior of the body as a result of research with isotopes. On the other hand, he faces the prospect of being called upon to provide medical care for a large number of victims of radiation injury as a consequence of atomic warfare. Most good physicians would like to understand not only the method by which new knowledge is acquired but also the pathogenesis of the injuries he may attend. Realization of this need on the part of the general practitioner is the reason for the preparation of *Atomic Medicine.* In his Preface Captain Behrens states that: "An earnest effort has been made to assemble such material as is appropriate to the needs of the medical and allied professions, and to present it as clearly as possible, steering a middle course between a presentation suitable only to specialists in the fields of radiation biology and physics, and one unduly elementary."

The reviewer believes that Captain Behrens and his associates have done a good job. There is a general scarcity of mathematical formulae which is unusual in any current work on atomic affairs. The explanations of complex nuclear reactions should be understandable to any educated person. The book, as a whole, is a reliable compendium of useful and practical information about the nature of nuclear radiations and their effect on man. Inevitably, there is some overlapping of the material in sections prepared by different writers, but this is not a serious defect. In a book prepared primarily for physicians, it would be better to discuss the clinical applications of radioisotopes in greater detail and more critically. The literature contains many reports which are confusing to the average reader. It is appropriate for a textbook to provide careful summation and evaluation, rather than to reproduce the published material without comment.

Viewing the book as a whole, one cannot fail to appreciate the dilemma of the physician: a great deal is known of the physical circumstances responsible for radiation injury; virtually nothing is known about specific means of treatment.

The challenge to research is great; and until medical scientists can develop successful methods of treating radiation injury, lay fears will persist. In the light of contemporary political events, it is interesting to note the attitude of naval medical personnel to the problems of atomic warfare. It is obvious that the Navy's Bureau of Medicine and Surgery is devoting a considerable effort to these problems. Regardless of the views of their strategists on the importance of the atom bomb, it is reassuring to know that the medical service is studying it seriously.

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Radioisotope Unit
Hines Veterans Hospital

Nuclear Physics. By ENRICO FERMI. Chicago: University of Chicago Press, 1950. Pp. 246. $3.00.

Out of My Later Years. By ALBERT EINSTEIN. New York: Philosophical Library, 1950. Pp. 279. $4.75.

Phenomena, Atoms and Molecules. By IRVING LANGMUIR. New York: Philosophical Library, 1950. Pp. 436. $10.00.

Planning National Defense, 1950 to 1970. By S. ARTHUR DEVAN. Washington: Library of Congress, September 1949. Public Affairs Bulletin No. 75. Pp. 105.

A Policy and Program for Success. By DEWEY ANDERSON and STEPHEN RAUSCHENBUSH. ("Bold New Program Series" No. 1.) Washington: Public Affairs Institute, 1950. Pp. 76. $0.40.

Reflections of a Physicist. By PERCY W. BRIDGMAN. New York: Philosophical Library, Inc., 1950. Pp. 392. $5.00.

Searchlight on Peace Plans: Choose Your Road to World Government. By EDITH WYNNER and GEORGIA LLOYD. New York: E. P. Dutton & Co., 1949. Pp. 607. $7.50.

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MINUTES TO MIDNIGHT

The International Control of Atomic Energy

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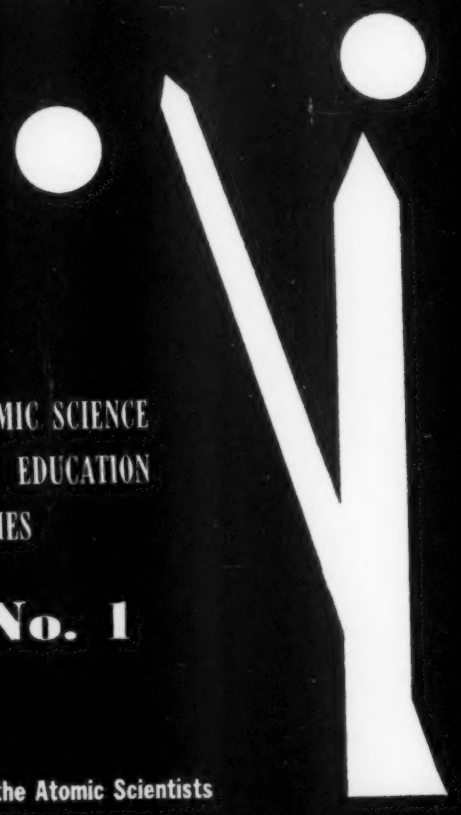

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